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Master’s in Environmental and Energy Management (MEEM)

Master’s Thesis

Challenges in the utilization and circularity of renewable energy: the case of small islands in Greece

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Abstract
Shifting to renewable energy sources from fossil fuel for electricity generation and other uses is a challenging process. Specifically, in the Greek islands, where the potential for renewable energy is significant due to the favorable climate and morphology conditions, this ongoing transition is facing a number of challenges and opportunities. Three small islands in Greece are researched as case studies, from the point of view of renewable energy utilization and circularity integration potential.
The current situation of the islands regarding renewable energy and circularity, the different approaches in the implementation of renewable energy sources and the different elements of these challenges and opportunities are discussed and highlighted. Finally, a list of 5 criteria is compiled, through which the potential of renewable energy utilization and circularity integration in small islands in Greece can be assessed for an effective implementation.

List of acronyms

EU: European Union
RES: Renewable Energy Sources
PPC: (Hellenic) Public Power Corporation
EMO: Energy Market Operator
ERA: (Hellenic) Energy Regulatory Agency
IPTO: Independent Power Transmission Operator
HEDNO: Hellenic Electricity Distribution Network Operator

kW: kilo Watt (10^3 Watt)
MW: Mega Watt (10^6 Watt)
TW: Terra Watt (10^9Watt)
Wh: Watt hour (10^6 Watt x 1 hour)
EIA: Environmental Impact Assessment
VAT: Value Added Tax
CSR: Corporate Social Responsibility

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All photographs and maps found in this research are the author’s work, unless otherwise stated.

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1. Introduction

1.1. Background

Energy adequacy has been considered as one of the most important and strategical aims for developing Greece, after the Second World War and the civil conflict that followed had left the country in ruins. Building infrastructure and providing access to energy to the sum of the population has been an enormous task, given the challenging geography (mostly mountainous, many islands) and the lack of infrastructure, such as roads and railways at the time. In the first years of the country's electrification, connecting the small towns and islands with the main grid was not financially feasible so, small private or municipal power plants were built, using coal and diesel as fuel, all imported. Due to this setup the price of energy ranged from triple to quadruple of the price in an average European country. By 1950 around 400 organizations of electricity production were active in Greece. In the same year, the public power corporation (PPC) was founded. The main priorities were to unify the grid and to make the country energy independent so, the exploration of the large lignite reserves and utilization of the hydro potential were initiated as well as the unification of the energy transportation grid (Energy Regulatory Authority of Greece, 2018).

However, by the end of the 1970's it was becoming clear that the environmental impact of the rapid development could not be ignored. A turning point in the social awareness was the huge pollution in the country's capital, Athens, that forced authorities to ban car access to the center of the city by the beginning of 1980. At the same period, the construction of a large lignite mine and power plant in Peloponnese region sparkled unprecedented, wide social protests. Additionally, after the global shift towards a more sustainable future and the joining of the European Union in the beginning of the 1980's, a structured discussion on sustainability and long-term planning was initiated, which led to the shift of energy planning strategy and today's situation.

The current strategy for energy in the country is shaped by the regulatory and legal framework which currently focuses on the following general axis(Greek ministry of Energy and Environment, n.d.):

1. Access to a wide variety of energy sources
2. Construction of oil and natural gas pipelines within international networks
3. Increased use of domestic energy sources and stocks
4. Reduced dependence on certain high-risk energy sources
5. Development of RES installations with the granting of incentives
6. Use and diffusion of clean and efficient environment friendly technologies
7. Liberalization of the market, increased competitiveness and putting an end to monopolies in the electricity and natural gas sectors.
8. Establishment of a healthy investment climate for businesses in the energy sector
9. Energy savings for industry, transport, buildings and homes
10. Establishment of national targets for the increased penetration of energy generated from RES, the reduction of greenhouse gas emissions and energy saving.

A basic analysis of the above strategic goals shows that the Greek governmental policy, being in a very sensitive geopolitical area, is aiming at balancing the energy independence and transportation as well as meeting the goals of sustainable development.

The different energy sources in Greece vary; 66.5% of the installed power of electricity plants are thermoelectric plants based on lignite, diesel and natural gas, 19.6% is produced by hydroelectric plants while 13.9% comes from renewable energy sources such as wind and solar (Energy Regulatory Authority of Greece, n.d.-a). Construction of oil and natural gas pipelines may not be a part of a purely sustainable investment, but from a geopolitical point of view, it is a move to improve Greece's energy independence, as some of the current oil routes pass through historically unpredictable areas, such as the Dardanelles.

Use of domestic energy sources can be reflected in the increased participation of renewables such as wind and solar in the grid, but with the lignite remaining the main traditional energy source. It accounted for 53.15%

of the local energy production in 2011. The estimated availability of lignite reserves is less than 35 years, so new fossil fuel sources are assessed, such as coal in order to increase the lifespan of lignite reserves. However, this will depend upon the success of the coal electric plants to comply with the emission levels defined by the Kyoto agreement (Energy Regulatory Authority of Greece, n.d.-a).

A good example of the challenges that such a shift to renewable energy include is the attempt of Greece to become a leading country in the production and export of solar energy. In 2010, right in the peak of the debt crisis, an ambitious project by the name of "project Helios" aimed at building an enormous (800 MW) solar power plant in the exhausted lignite mine areas and export the energy to central Europe, mainly Germany. (Hellenic Ministry of Environment & Energy, 2011). The project had such visibility that was a part of the agenda of the top summit of the EU leaders in 2011. Unfortunately, the project was frozen as the costs of upgrading the grid capacity for the export was more than expected and none of the countries where the connection would pass through had the funds to upgrade their corresponding transfer networks. (Energypress.gr, 2013).

Greece is a country with more than 6000 islands, with around 90 of them inhabited (2011 census, n.d.). Several of them are of a small scale (<3000 pop). These islands are facing plenty of challenges because of their rough natural landscape (rocky, windy, dry) as well as because of their isolation especially during the winter months when sea conditions can make islands inaccessible for days.

In this sense, supply is a constant challenge for the islands. Energy wise, most of the small islands are not interconnected with the national grid and rely on small thermoelectric power stations, usually with diesel generators. In the landscape of the Greek islands, where there is one of the highest number of sunny days among the EU, and additionally with a very high wind energy potential, it is an obvious choice to invest in renewable energy for the electricity efficiency of the islands. Therefore, this research will: (i) examine the current energy situation in three Greek islands; (ii) try to identify bottlenecks in increasing the participation of RES for achieving energy autonomy of each island and; (iii) attempt to provide recommendations for reaching the goal of the islands having a positive RES energy balance and becoming self-sufficient by using renewable energy. Additionally, the whole concept of circular economy in the islands will be looked at, including the energy point of view. The reason behind this choice of island size is the relative small number of energy needs, and therefore the small size of any needed initial investment. Also, an island is a closed system, where bottlenecks and problems become easily visible, therefore, it can act as a small-scale model of a larger implementation of a working policy.

1.2. Problem statement

The Greek islands, large and smaller ones, have all the potential to produce enough energy to meet their needs and even be 100% energy neutral by using renewable energy sources, as they are favored by their special climate conditions. This can be achieved by a combination of solar, wind, geothermal, hydro and biomass energy sources. The excess of energy can be diverted to the main grid in the case of islands that are connected with the electricity transmission network while in the non-connected islands the excess of energy occurring during the months of the low demand can be utilized for meeting the energy needs of desalination, heating, waste water treatment or be stored with different technological options (Kaldellis, Gkikaki, Kaldelli, & Kapsali, 2012). However, the Greek islands are still in a relative low level of renewable energy utilization, especially smaller islands where the technical obstacles of implementing the needed infrastructure is of relative low cost and low technical complexity, while the current energy production technologies used are very costly and unsustainable.

Therefore, there is the need to analyze the progress towards this goal, focusing on the technological challenges, governance delays, decision making and authorization processes as well as the possible bottlenecks in the whole procedure toward this goal.

1.3 Methodology

1.3.1 Research framework

This research will be based on desk and field research. The preparatory part will focus on the existing policies, structure of stakeholders, decision making procedures, long and short-term planning and community responses, while the field research will focus on assessing the actual situation of the ground by contacts of various stakeholders in the islands and the capital of Greece. A special focus on the link of circularity and renewable energy sources will be attempted. The findings of the research will be analyzed based on criteria that will be defined by categorization of the internal and external factors as well as based on the common pool resources theory as researched by E. Ostrom(Ostrom, 1990).

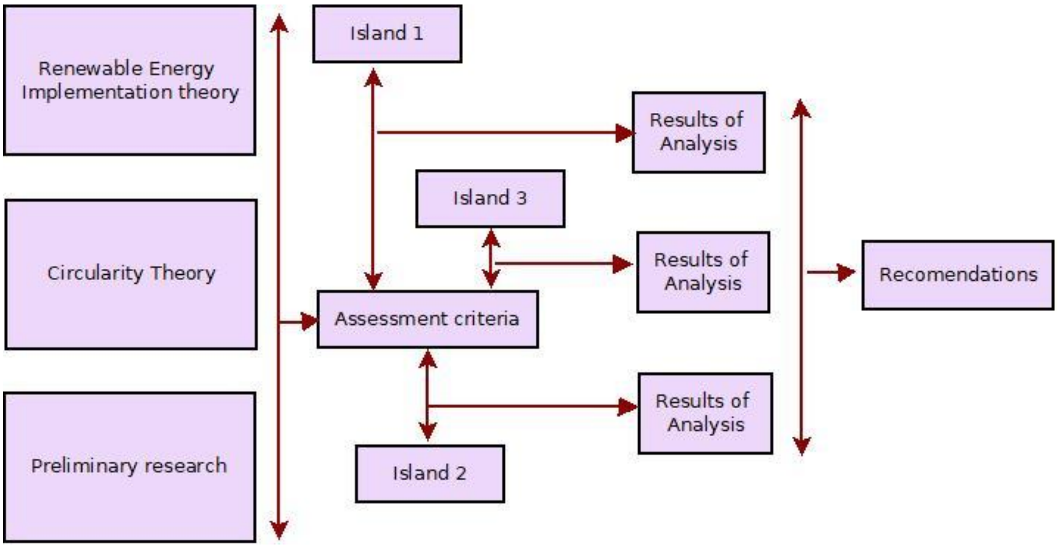

Figure 1: Conceptual model of the research methodology

1.3.2 Main and secondary research questions

Based on the above research framework, the main research question is related to the general situation of the islands regarding renewable energy and is formulated as below:

"*What is the potential of renewable energy utilization and circularity integration in small islands in Greece and what are the main relevant criteria for assessing their effective implementation?*"

The secondary research questions focus on the specific, current situation of the islands and the particularities of the implementation of the goal of increasing the renewable energy sources:

a. "*What is the current energy and resource situation on the Greek islands?*"

b. "*What is the potential for utilization of renewable energy sources and implementation of the principles of circular economy in small Greek islands?*"

c. "*What criteria could define the effective implementation of utilization of renewable energy sources and implementation of the principles of circular economy?*"

1.3.3 Research methodology

The objective of this research is to provide a list of recommendations applicable to small, isolated communities to increase and optimize the utilization and circularity of renewable energy by analyzing and comparing 3 small islands in Greece.

Greece is a country with more than 6000 islands, with around 90 of them inhabited (Hellenic Statistics Authority, 2011). Several of them are of a small scale (<3000 pop). For this research we define as "small" islands with population less than 3.100 inhabitants. This categorization is based on the Greek government taxation categorization that was in power until the end of 2015. The islands with population less than 3100 are 72, according to the 2011 census. However, a more realistic number of islands with actual communities, would be closer to 53. That is because the 19 remaining islands have populations of less than 30, which are usually temporary residents, such as herders, antiquities watchmen and touristic enterprises employees (Hellenic Statistics Authority, 2011). In Greece population census takes place every 10 years, with last one being on 2011.
Additionally, the small islands researched were chosen in order to represent both categories; interconnected and not interconnected with the main electricity transmission grid.

The research approach was qualitative, based on document analysis, literature research, analysis of public information (specialized web sites, official ministries and agencies web pages) and five semi-structured interviews with key actors. The interviews were conducted on site, face to face, during June 2018. The interviews were recorded, and a summary of the key points was transcribed. The main idea on the choice of interviewees was to have one key person from each one of the islands researched, as well as experts from the private sector, active in RES, and an expert from the ministry of Energy & Environment.

Interviewee	Organization
Iakovos Roussos, Mayor of Anafi island	Municipality of Anafi
Christofis koroneos, Mayor of Nisyros island	Municipality of Nisyros
Stathis Kontos, Special advisor to the Mayor of Tilos island	Municipality of Tilos
Technical Expert	PPC Renewables
Political/ Technical Expert	Party of "Ecologists-Greens", Ministry of Energy & Environment

Table 1: List of Interviewees

1.3.4 Outline

Charter 1 introduces the context of Greece in a historical perspective, gives an overview of the energy production in the country, explains the challenges of the Greek landscape with the large number of islands. It introduces the problem of self-sufficiency in the islands, the research question and the sub questions. Finally, it presents the methodology that was chosen to approach the research.
Charter 2 presents the existing situation in the energy market in Greece, how the electricity network is functioning to power the islands, what is the RES situation in the islands, the planning and the cost of energy. It also presents the existing knowledge on the usage of RES in the islands, the innovation proposals, the existing situation on circularity and the concept of RES as "common pool resources".
Charter 3 gives an overview of the 3 islands chosen for this case study, including their morphology, population, energy situation, planning and societal attitude on RES.
Charter 4 is introducing an analysis of the three islands based on external and internal factors, such as policies, external funding, societal response and internal particularities, attempting to link those in interaction points. It also analyzes the finding using the typology of Common Pool Recourses.
Charter 5 is summarizing the outcome of the analysis, focusing on the main challenges and conclusions
Charter 6 concludes the research with reflections on the findings and suggestions on improvements for the future.

2. State-of- the-art

Renewable energy sources and circular economy principles are complex concepts that are rapidly evolving. In order to have an adequate understanding of the current situation, a detailed analysis, considering a number of political, technical and social aspects is required. This charter will describe the context of Greece from the point of view of renewable energy sources and circular economy.

2.1 Topography and particularities of the islands in Greece

2.1.1 Topography, climate

It is important to define the particularities of Greece before any further analysis, and especially the islanding concept, which is essential. Greece is a country with a large number of islands (more than 6000 islands and islets) and one of the most extensive coastlines in the world (more than 15.000km) (Hellenic Tourism Organization, 2018).

Islanding is more than just a simple geographical system. It is a combination of a geographic situation with political, social, economic and cultural elements. The geographic permanent features such as low accessibility and small size, have a significant impact on the economic and social development of the islands, thus increasing the need to weigh the key socio-economic indicators. The small size of the market and the smallest competition affect productivity, as well as working conditions and living. The topography of the islands has significant economic implications and geographic features.

Islanding is associated with characteristics which can be categorized according to (Bass, Dalal-Clayton, & International Institute for Environment and Development. Environmental Planning Group., 1995) to the following characteristics, adapted for the Greek context:

1. The narrow economic base
2. The economic dependence on maritime and air transport
3. The geographical isolation which can significantly reduce economies of scale
4. The small populations and as hence a limited pool of skills (human resources) and reduced competition on the labor market in terms of attracting people potential
5. The strictly defined area and the resulting lack of natural resources
6. The high shoreline to land ratio, leaving the islands vulnerable to marine and climatic impacts, such as cyclones, hurricanes, storm waves, corrosion due to salt and marine pollution
7. The vulnerability of island ecosystems to other external ecological effects, such as the introduction of exotic species or the extension of endemic species

The intense seasonality and vulnerability in climate disasters, small size, and their remoteness, inconsistency in policies at both national and community level act as a handicap for the development of the islands compared to the mainland.

The Greek islands climate can be categorized in 2 seasons: dry and windy summers and mild winters, making the islands a favorable tourist destination during the summer time. These two seasons also define the economic activities in the islands as touristic activities can lead to multiplication of the island's population and economic activity by many times. This huge increase also stresses the energy production system that faces many challenges in managing the availability of energy during the peak season.

2.1.2 Challenges of access, electrifying, geopolitics, uninhabited islands


Figure 2: Wind turbines on the uninhabited island of st. George, Greece

Given the large number of islands in the Greek seas, with most of them uninhibited, the development of RES on islands appeared as an opportunity and has been included in the strategic planning of energy in Greece, especially the possibility of using uninhibited islands as platforms for installation of wind farms and solar parks (see Fig. 2). This kind of investment is beneficial, as it utilizes unused land and can facilitate the electrical connection between island and supply – demand needs (Hellenic ministry of environment and energy, 2013). However, interconnection of the islands has always been one of the main challenges due to the distances, small size of islands and the nature of the Greek seas. It requires a high initial investment for the needed infrastructure (port, roads, etc.) as well it is highly dependable on the location of the islands as most of the Greek seas are very deep and underwater cables not technically feasible (Kaldellis et all, 2012). Other obstacles can also appear; such as the historical heritage of the islands and the protection regulations against any alternation of the landscape. Characteristic cases are the islands of Gyaros and Makronisos, that were used as exile areas for political prisoners until the 1970's and any installation of RES would trigger large communal opposition as well as lengthy permission procedures.

2.2 Electricity generation, transmission and distribution in Greece

One of the priorities of the European Commission was the Energy Union, intending to have reliable, affordable and environmentally friendly provision of energy to the consumers. Based on this priority, liberation of the electricity market was implemented since the 1990's, as most of the member states had state owned monopoly enterprises in the electricity market. Energy was now considered as a commodity and is market operated as a regulated market. This change had ideological grounds; it was on the view that the state is inefficient and by creating open, competitive markets the levels of investment, innovation will increase while the consumers would have to pay lower prices (Roelich & Knoeri, n.d.)
The priorities for the implementation of this goal were the following:

- Having a clear distinction between competing activities, such as the provision of electricity supply to consumers and the non-competitive activities, such as the network operation
- The obligation of non-competitive business operators to allow third parties access to their infrastructure such as network connection
- Liberalization of electricity supply activity through lifting the barriers of electricity production for alternative suppliers.
- Gradual elimination of limitations on choice of supplier for the consumers
- Setting up independent market surveillance regulators

These goals were regulated with the EU directives 1996/92/EC, 2003 54/EC and 2009/72/EC and were embedded in the Greek legal framework with the laws 2773 of 22/12/1999, 3426/2005 and 4001/2011. Following this, the electricity market in Greece has been restructured, as previously the sum of electricity in Greece was managed by the PPC.
Based on these regulations, the Greek state supervises all activities related with the market of electricity within the framework of the long-term country's strategy, which is harmonized with the EU one, aiming at securing energy supply, protecting the environment, balancing regional development, productivity and

competitiveness of the national economy, and achieving healthy competition to reduce energy costs for all users and consumers (Hellenic Ministry of Environment and Energy, n.d.)

Following these, the Greek system of Electricity is divided into the interconnected and the non- interconnected grid. In the interconnected grid both production and distribution of electrical energy are competitive activities where both the PPC and private enterprises participate.

In the production part, PPC holds around 60%, alternative producers 14% and RES 25%, while in the transmission, PPC holds 92% of the network and the alternative providers 8%.

The electricity market is regulated by the "Electricity Market Operator" (EMO), which operates in the principle of "pool structure" This means that the sum of available power in the country feeds a "pool" which feeds all participants in the transmission leg of the electricity network and from there to the consumers. Therefore, even PPC has to feed the "pool" with the produced electricity and then buy it under the same terms with the rest of the alternative providers in older to supply the consumers.

The market is operating based on the market law of supply and demand; Energy is produced and fed in the system, starting from the cheaper one, until there is a balance reached with the demand. This balance point is defining the "system marginal price", which is the price requested by the last production unit that entered the system in order to cover the demand. Therefore, in period of high demand the system has to absorb power from the production in higher prices. This means that the lignite-based production is the first one used, followed by the hydroelectric units and finally the natural gas ones. RES are an exception to this system, as the available power from RES is prioritized when fed in the system, since RES operate under the feed-in tariffs which guarantee a minimum price for the produced energy, even if the system marginal price is lower. This gap is covered by the funds of the special fee for RES that is included in all the electricity bills for all consumers.

Regarding the transmission network, it consists on the transportation network, which is the high voltage one, and the distribution network which includes the medium and low voltage grid.

The management of the transmission network, which is also owned by PPC SA, was assigned to the company "Independent Power Transmission Operator " (IPTO). IPTO is a 100% subsidiary of PPC but is completely independent in terms of both operational and administrative. Its revenues are provided by the operation, maintenance and development of the transmission network and the provision of access in the system to holders of a license to produce, supply or sell electricity.

The manager of the distribution network which includes the medium and low voltage grid is the company "Hellenic Electricity Distribution Network Operator", which was established with the split of the PPC distribution sector. It is 100% affiliated company PPC, however it is in accordance with the provisions of the above law, it is functionally and administratively independent. Ownership of the Greek Electricity Distribution Network belongs to PPC. An overview of the various operators in the Greek energy market can be found in Table 2.

The non-interconnected islands operate under a different system; the operating and management of the market is performed by the IPTO, based on the relative code of RAE. Therefore, the electricity production sector is entirely liberal, however there is no access to the pool of energy market that exists in the mainland grid. And since the cost is higher than the one of the mainland, as production is more challenging, the production of electricity is subsidized in order to cover the excess cost and have the same price as the one for the consumers in the mainland.

Name	Acronym	Scope
Public Power Cooperation (Δημόσια Επιχείρηση Ηλεκτρισμού)	P.P.C (Δ.Ε.Η)	The previous state monopoly in Energy. Holds assets in lignite mines, power generation, transmission and distribution. PPC's current power portfolio accounts for approximately 68% of the total installed capacity in the country.
Electricity Market Operator (Λειτουργός της Αγοράς Ηλεκτρικής Ενέργειας)	E.M.O. (ΛΑΓΗΕ)	Implementation of the rules of operations of the Electricity market and the daily Energy planning
Energy Regulatory Agency (Ρυθμιστική Αρχή Ενέργειας)	ERA (PAE)	Supervision of all sectors of local energy market, reporting to all relative state agencies and taking measures for meeting the goal of liberation of the electricity and natural gas markets.
Independent Power Transmission Operator (Διαχειριστής του Ελληνικού Δικτύου Διανομής Ηλεκτρικής Ενέργειας)	IPTO (ΔΕΔΔΗΕ)	Management, operation, maintenance and development of the Hellenic Electricity Transmission System and its interconnections. 100% subsidiary of PPC
Hellenic Electricity Distribution Network Operator (Ανεξάρτητος Διαχειριστής Μεταφοράς Ηλεκτρικής Ενέργειας)	HEDNO (ΑΔΜΗΕ)	Management, operation, development and maintenance of the Hellenic Electricity Distribution Network. 100% subsidiary of PPC

Table 2: Overview of the Greek Electricity Market Operators

2.3 Islands and their connection to the network

The current strategy of energy production of the islands is based on autonomous production stations, operating on diesel fuel. As the demand varies largely between the low and the high (the touristic) seasons in the islands, the excess demand of the peak season is managed with movable generators, that are transferred from one island to the other, according to the demand (Patlitzianas & Karagounis, 2011). A typical setting in a small island would consist in 6-8 generators, where 2 are connected to the grid and are in sync, while there are at least 2 more running idle and are ready to connect to the grid when demand increases, named "hot reserve". The rest of the generators are switched off but are operational and can enter the production, with a longer time until they can connect ("cold reserve") (Political/ technical expert Ministry of Environment, 2018). These solutions have a significant higher cost of production compared to the cost of production in Greek mainland. The average cost in 2009 was around 200 €/MW, while in the small islands the increased transport cost would increase the cost to even 1000€/MW (Kaldellis et al., 2012). Over 82% of electricity in non-interconnected islands in 2017 was produced by oil fueled plants ("Hellenic Energy regulatory Agency, Non-interconnected islands," n.d.) , resulting in the abovementioned high production costs and stress to the environment. However, switching to a similar autonomous system for each island based on RES would, obviously, not be feasible as the fluctuation of the energy production would demand a significant dependency on the traditional oil-based generators. Therefore, the interconnection of the islands among them and with the mainland, in second phase, is the long-term solution, that can also support a transition to a RES based energy production system.

The energy needs of the islands are covered by a combination of technical solutions;

a) With direct interconnection with the mainland through underwater cables
b) Clusters of islands that are interconnected
c) Non- interconnected, autonomous islands

Figure 3: Map of the existing island interconnections (source: ERA)

Most of the islands in Greece (mainly in the Aegean) are powered by stand-alone, local thermal power stations, which run on oil as well as RES (wind and photovoltaic). These islands have not been interconnected so far with the mainland electrical grid because of technical difficulties, but also because of financial constraints, since connecting the islands in a deep sea such as the Aegean requires a major investment. There are 32 Non-Interconnected Islands which are based on autonomous systems (see fig. 3), including the clusters of islands (categories b &c) and the operation of the systems is managed by the Hellenic Electricity Distribution Network Operator, island division.

The peak demand in kW of thirty-two (32) autonomous island electrical systems in the country varies; Nineteen "small" stand-alone systems have peak demand of up to 10 MW, eleven “medium-sized" stand-alone systems have a peak demand of 10 MW to 100 MW and two “large" autonomous systems have a peak demand of more than 100 MW, namely Crete and Rhodes. Likewise, the demand (consumption in MWh) of electricity varies from a few hundred MWh to the smaller islands (eg Anafi) up to some TWh in the largest island (Crete).

Out of the islands researched in this document, Anafi is the only one falling in the third category. Nisyros and Tilos are part of the cluster that includes Nisyros, Tilos, Kalymnos, Kos, Leros, Pserimos, Telendos and Gyali (Fig. 4). These 8 islands rely on the thermal power plant in Kos island that powers the rest of the islands through underwater cables of 20kV.

Island`	Installed Power (kW)	Maximum power demand (kW)	Yearly consumption (MWh)
Anafi	355	340	607
Nisyros, Tilos, Kalymnos, Kos, Pserimos, Telendos, Gyali	69.600	59.300	217.824

Figure 4: Installed capacity in the islands researched

The average cost of the MWh was 177,34 € for the year 2013 (Hellenic Energy regulatory Agency, n.d.)

Expanding the connection lines between the islands is a large project last has been implemented for years and is continuing to expand in the long term. The current network expansion is focusing on the islands of Cyclades prefecture and is distinguished in three phases. The first phase of the interconnection includes the islands of

Syros, Mykonos, Paros and Naxos, with a budget of € 245 million. The second phase involving the interconnection of Naxos and the upgrading of the interconnections with Andros and Tinos is expected to be completed in 2019 while in 2020 the third phase is planned, which includes the laying of a second interconnection cable between Lavrio and Syros. In the same year (2020), the first "small" interconnection of Crete via the Peloponnese - Chania will be launched, followed by the second one (Heraklion - Attica), while the interconnections of islands of Central and Northern Aegean and Dodecanese are in the planning phase.

The interconnection project is believed that will provide reliable electricity provision to the islands for the next 30-40 years and is expected to reduce the current operational cost € 600-800 million per year.

2.4 Sustainable Energy, potential neutrality and self-efficiency

Kaldellis et al, et al. (2012), have performed a case study on the possibility of energy autonomy of Agathonisi, a small island of comparable size and population with the ones researched in the current document. The proposed system included wind turbines, photovoltaic panels, batteries and internal combustion generators using biogas. The later ones are planned to cover the peak needs of demand, as this technology allows the generators to synchronize with the grid very rapidly at periods of high demand. The excess of the generated electricity is allocated for powering the desalination of sea water, as all Greek islands are facing drinking water shortages, with more than 2.500.00 m^3 of drinking water transferred to the islands from the mainland each year (Kaldellis, Kavadias, & Kondili, 2004). Moreover, Mentis et al., (2016), showed that desalination using renewable energy sources in the islands could considerably reduce drinking water cost from 7-9 €/ m^3 to approximately 2,6€/m^3. In another study, Mourmouris & Potolias, (2013) have developed a framework, that uses quantitative and qualitative criteria, to calculate the optimal amount of each renewable energy source (solar, wind, biomass, etc.) that can be produced in a region and to contribute to an optimal energy mix. However, since the whole island system is one of many isolated smaller systems, the optimal use of renewable energy resources cannot be fully utilized without the connection of the Greek islands between them and with the mainland grid, as it was stressed by Zafeiratou & Spataru, (2015), using the larger island of Syros as a case study. Haralambopoulos, Pantelakis, Paraskevas, & Lekkas, (1997), have also argued for the connection of the smaller islands, together with the study of utilizing renewable energy in island waste water treatment plants.

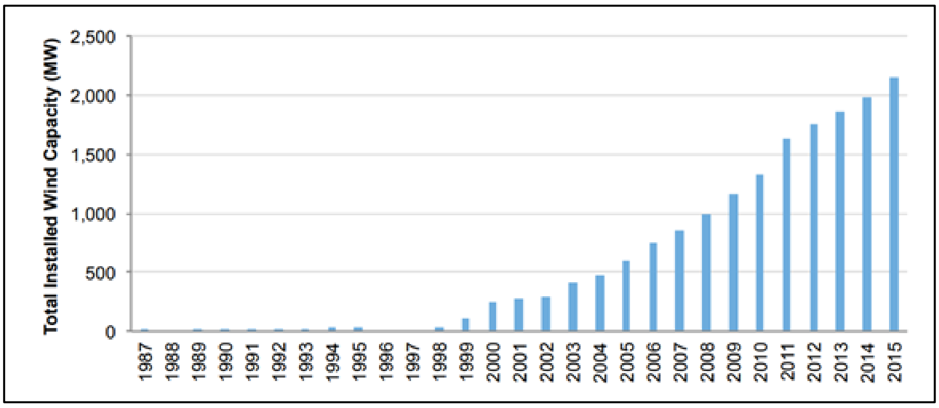

Figure 5:Total installed wind capacity in Greece 1987–2015
Source: HWEA. (2015, June).

According to the Hellenic Wind Energy Association, 176 wind farms operated in Greece at the end of 2015 with a total capacity of 2.152 MW (Fig. 5, 6). However, since the country's target, as set by "the National Renewable Energy Action Plan", is to reach 7 500 MW by 2020, the country has to significantly increase its wind energy, as the current average increase rate of 14% (see figure 3), will not be sufficient to meet the goal by 2020, which would require an increase of more than 400% yearly. The main barriers for increasing the wind power yield, especially in the islands region (Aegean Sea) is technical, such as grid instability, supply/ demand mismatch, lack of energy

Table 1. Key National Statistics 2015: Greece

Total (net) installed wind capacity[a]	2,152 MW
New wind generation installed[a]	172 MW
Total electrical output from wind[b]	3.5 TWh
Wind-generated electricity as a % of national electric demand	***7.1***
Target:	7,500 MW by 2020

Bold italics indicate estimates
[a]Hellenic Wind Energy Association (HWEA) Wind Energy Statistics 2015
[b]ENTSO-E [1]

Figure 6: Wind energy Statistics 2015 (source HWEA)

connections between islands and logistics constraints, especially during the winter months (Kaldellis, Kavadias, Papantonis, & Stavrakakis, 2006)

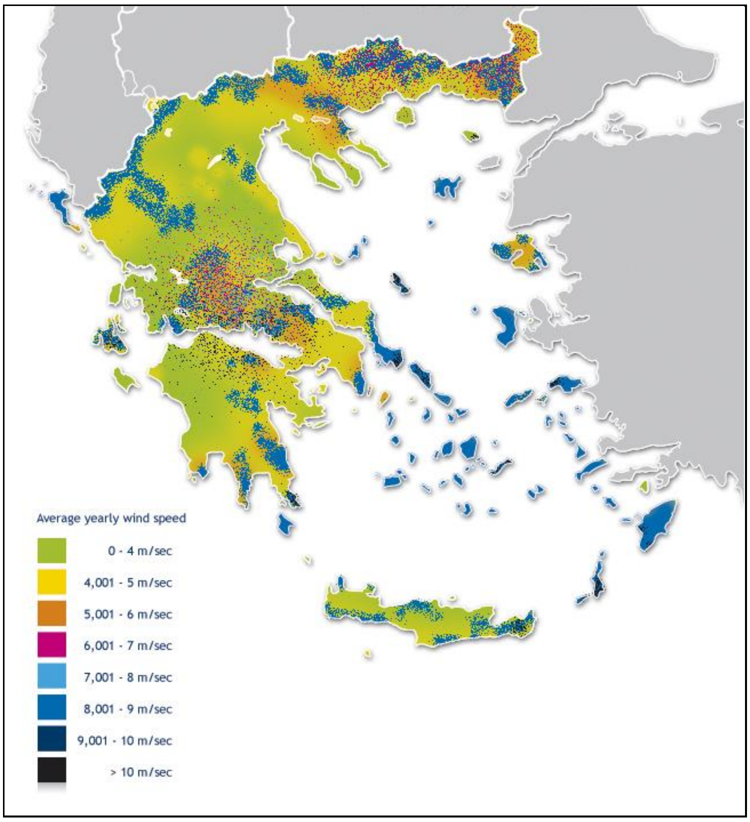

Figure 7: Wind energy potential in relation with average wind speed in Greece (source: investingreece.org)

2.5 Circularity potential in small islands

The concept of a circular economy has gained a lot of growth during the last years. As a basic definition, a circular economy aims on replacing the current linear economic model, where resources are harvested, manufactured, used and disposed, with a more sustainable one which will not compromise the ability of future generations to meet their own needs. This ambition is based on three main principles; of design out waste and pollution, keeping products and materials in use for as long as possible and regeneration of natural systems (Ellen McArthur Foundation, 2017) (See figure 8). However, there is no commonly accepted definition of the concept of circular economy, as shown by Kirchherr, Reike, & Hekkert (2017), since 114 different definitions of circular economy were reviewed for their study. Nevertheless, they concluded that a combination of "reduce", "reuse" and "recycle" activities is portrayed most of the times, with additional stress on the systemic shift that an implementation of circular economy would require.

A compact summarization to the circular economy principles can be also found with the ReSOLVE approach, as introduced by the Ellen Mc Arthur foundation ("Circular Economy System Diagram - Ellen MacArthur Foundation," n.d.). ReSOLVE is an acronym for Regenerate, Share, Optimize, Loop, Virtualize and Exchange. A summary of these definitions can be found in table 3.

Regenerate	Shift to renewable energy and materials
	Reclaim, retain, and restore health of ecosystems
	Return recovered biological resources to the biosphere
Share	Share assets (e.g. cars, rooms, appliances)
	Reuse/secondhand
	Prolong life through maintenance, design for durability, upgradability, etc.
Optimize	Increase performance/efficiency of product
	Remove waste in production and supply chain
	Leverage big data, automation, remote sensing and steering
Loop	Remanufacture products or components
	Recycle materials
	Digest anaerobically
	Extract biochemicals from organic waste
Virtualize	Dematerialise directly (e.g. books, CDs, DVDs, travel)
	Dematerialise indirectly (e.g. online shopping)
Exchange	Replace old with advanced non-renewable materials
	Apply new technologies (e.g. 3D printing)
	Choose new product/service (e.g. multimodal transport)

Table 3: The ReSOLVE framework (Ellen MacArthur Foundation)

In the case of Greece and the islands, the implementation of circular economy is evolving around several possibilities. One of the most prominent is the waste-to-energy potential, which can have a wide number of possible applications for valorization of the waste in the Greek island context, such as anaerobic digestion and biofuel production, as presented in a literature overview by Loizidou, (2015, 2016). Additionally, the possibilities of sewer-mining, as a mean to improve water scarcity in the Greek islands, as well as an entrepreneurship option was presented in the research of Makropoulos et al. (2017).

In the context of the small Greek islands that this research is focusing, the main economic activity is based on agriculture, fishing, the primary production sector, and tourism. Therefore, the circularity has to focus on small scale ideas, community-based approaches with the support of the municipality in terms of know-how and coordination. Circular economy can operate as a small scale approach of industrial symbiosis, which "examines cooperative management of resource flows through networks of businesses known in the literature as industrial ecosystems" (Chertow & Ehrenfeld, 2012). Therefore,

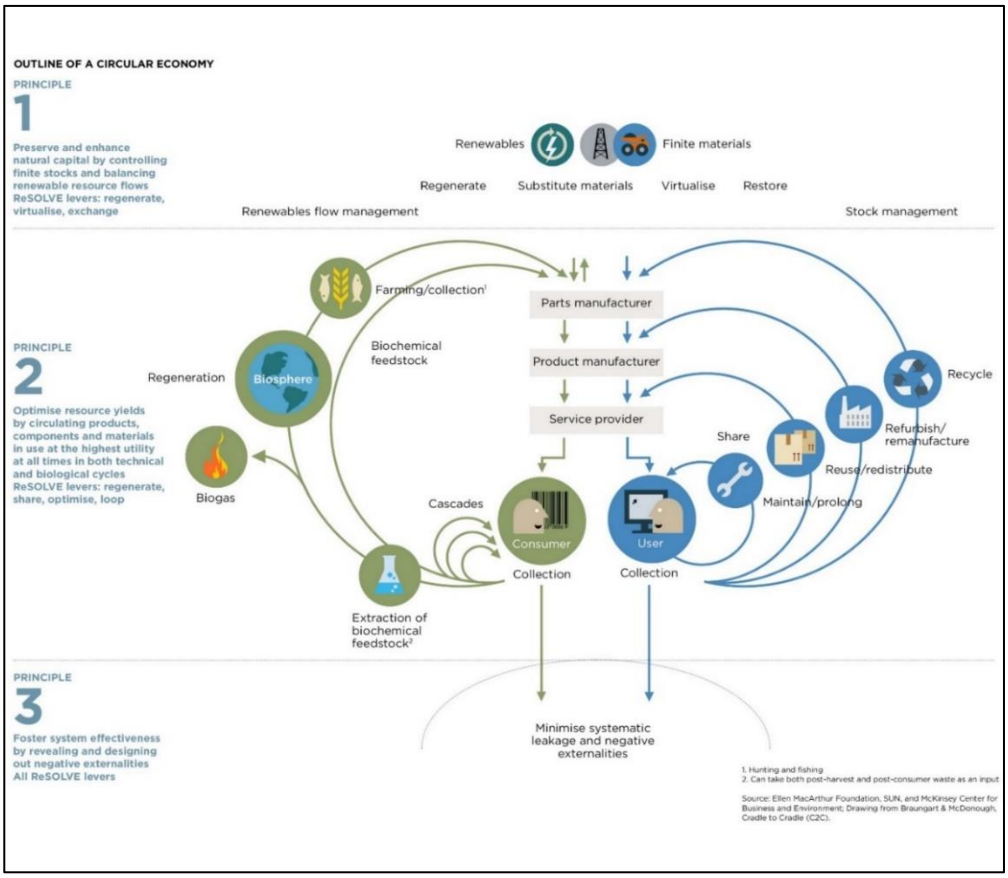

Figure 8: An outline of a circular economy (Ellen McArthur Foundation, 2017)

symbiotic exchanges of material and energy and recognition of the mutual benefits of such a self- organized system are feasible, not in a full industrial scale, but more in a small- medium enterprises level, as researched by Cecelja et al. (2015), or innovative uses such as the use of grape marc, a waste product of a winery, for desalination of water containing copper (Bustos, Calvar, Vecino, Cruz, & Moldes, 2018). In the case of Tilos, the seasonality of the touristic season that is incompatible with the seasonality of the agricultural products of the island can be addressed by the creation of a community canning artisanship that can utilize the excess of the local winter's production to the touristic market, which would otherwise be disposed (Stathis Kontos, 2018)

2.6 Common Pool Resources in the islands

A Common pool resource (CPR) is a type of good "consisting of a natural or human-made resource system whose size or characteristics makes it costly, but not impossible, to exclude potential beneficiaries from obtaining benefits from its use." (Ostrom, 1990)

Renewable energy sources can be considered as a Common Pool Resources, as it is impossible for any individual to have exclusive harvesting rights of the solar radiation or the wind, for instance. In this sense, the design principles for long enduring common pool resources, as described by E. Ostrom (1990), can apply in this case. These design principles are listed in Figure 9.

1. **Clearly defined boundaries**

Individuals or households who have rights to withdraw resource units from the CPR must be clearly defined, as must the boundaries of the CPR itself

2. **Congruence between appropriation and provision rules and local conditions**

Appropriation rules restricting time, place, technology, and/ or quality of resource units are related to local conditions and to provision rules requiring labor, material, and/ or money

3. **Collective-choice agreements**

Most individuals affected by the operational rules can participate in modifying the operational rules

4. **Monitoring**

Monitors, who actively monitor CPR conditions and appropriator behavior, are accountable to the appropriators or are the appropriators

5. **Graduated sanctions**

Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and context of the offence) by other appropriators, by officials accountable to these appropriators, or both.

6. **Conflict resolution mechanisms**

Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials

7. **Minimal recognition of right to organize**

The rights of appropriators to devise their own institutions are not challenged by external governmental authorities

8. **Nested enterprises**

Appropriation, provision, monitoring, enforcement, conflict resolution and governance activities are organized in multiple layers of nested enterprises

Figure 9: Design principles illustrated by long enduring CPR institutions (Ostrom, 1990)

Following these design principles, we can also define the terminology that is used in this concept:

Resource Systems are the larger stocks from which a good, in our case a renewable resource is appropriated.
Resource Units are the units that quantify the flow of the resources as they are being appropriated.

Providers are teams or individuals who arrange for the provision of a resource system at multiple levels, to ensure long-term stability or sustainability of the resource system.

Producers are teams and individuals who construct, commission, and maintain access to the resource system.

Appropriators are the individuals who make use of resource units.

Arbiter is a third party, as either an impartial person or an institution, that is given the power to decide among stakeholders in a controversy.

2.7 Societal acceptance

The transition to renewable energy sources has been marked with significant objections and opposition from individuals and the local civil society. Even if, in principle there is a general acceptance for RES, at the same time there is strong resistance to that development by communities living near the site of the proposed installation, which is often referred to as "NIMBY" (Not In My Back Yard) (Bell, Gray, Haggett, & Swaffield, 2013). This opposition is more evident for the case of wind farms.

According to Karydis (2013), "governments and investors are mainly interested in the economic aspect of wind farms. They sacrifice the natural environment at a local scale to respond to the increased demand for electricity". Especially when taking under consideration the diverse landscape, usually under environmental protection status and the touristic potential of the areas with the highest wind potential, it is easy to see the conflict of interest. A brief summary of the main arguments and fears when opposing to wind turbines and wind parks would be:

- Alternation of the landscape with aesthetic degradation, that will have a serious impact in tourism which is the main income for many of the residents
- Loss of value of land property
- Opening of roads in previously "virgin" areas and alternation of the landscape
- Affection of protected areas and their ecosystems
- Disproportionate size of wind turbines in islands that are small
- Concerns about bird and wild life mortality
- Concerns about the impact on the resident's health (noise, flickering, etc.)
- Concerns of abandoning the wind turbine facilities after their life span
- Concerns about desertification of the wind farm areas

In 2010, the Greek government established an incentives scheme for the local communities to increase the acceptance for RES projects, especially wind turbines installation. The communities would receive a special profit return of 3% based on the pre-VAT sale price of the electricity produced by RES in their area. Third of this amount will be directed to local residents as a credit on their electricity bills, 0.3% to a "green fund" to support Natura 2000 reserves and the remainder will be used to supporting local municipalities. A second measure was the clear definition of the special spatial framework for RES installation, giving guidelines and criteria for the locations and specifications of renewable energy projects. This framework consists of exclusion zones and distances from them, quantitative criteria for the assessment of visual impact and methodology. However, the local societies remain sceptic towards RES projects, with plenty of examples of opposition against them. A notable example is the case of St. George island, displayed in figure 10, near the prefecture

Figure 10: Aerial view of St. George (Source: TERNA co)

of Athens, where 23 wind generators producing a nominal 73,2 MW of electricity were installed on the uninhabited island. For the installation of the wind turbines there was a small port built for docking of the cargo boats, the hill tops were leveled through landfilling works and a total of 16 km of roads were created on the island for the needs of the installation.

The work took 2 years to be completed while the preliminary licensing procedure alone required 6,5 years, having acquired on-site inspections, approvals and supervision from 28 agencies of a total of 8 Greek ministries. The wind farm is operational since 2016. The investment was 150 million euro in total (ternaenergy, n.d.). The long period of licensing is reflecting the society's attitude towards such projects. The specific one fueled a debate among the Greek society. The main objections were focusing on the issue of the aesthetical alternation of the landscape, due to the proximity to the temple of Poseidon in cape Sounio (second most visited archaeological site in Attica after Acropolis). The debate had even reached the Greek parliament, where parliaments members would officially have questioned ministries of environment and public works for the licensing procedures, fearing the negative effect that this project will have on the landscape of cape Sounio (efsyn.gr, 2015).

Society Readiness Level

8 Project is not contested

7 Project details are contested

6 Technical and logistical aspects of the project are contested

5 The impact of the project is contested

4 The location of the project is contested

3 The technological concept of the project is contested

2 The project as such is contested

1 The value proposition of the project is contested

Figure 11:Social Readiness levels overview (Source: M. Arentsen Lectures)

Based on the typology proposed by Marten Arentsen (2017), society tends to react in the construction of projects of this magnitude, even if the project is considered to be an environmentally friendly one, such as a wind farm. In this typology, the readiness level of societies towards a specific project are categorized in 8 categories, based on the object of contest, such as the location or the technology used (see Fig. 11).

Another important aspect of the societal response to RES projects is the issue of trust. In Greece mistrust toward the government is quite common and there are several examples of citizens and civil society organizations opposing governmental plans claiming that the environmental commitments of the implementing companies are not reliable. Public opinion research companies have presented findings where institutions such as the parliament or the political parties have very low trust percentages: 70% mistrust level for the parliament and 84% for the political parties (Public Issue Research, 2015) . There are cases even where RES companies funded excursions of residents of areas where a potential RES installation was planned to countries where an identical RES technology was operating, in order to demonstrate the positive impact of the project, to receive the feedback that "even if this setting seems adequate, we don't trust that it will have the same standards in our municipality" (PPC Renewables executive, 2018). At the same time, mistrust is used as an argument in studies on the geothermal potential of Nisyros: "The high risk involved in electric production units and the subsequent dangers of mismanagement – not uncommon for the reek reality…" (Nisyrian studies Society, n.d.)

Nevertheless, participation of the community in the RES projects, as a kind of participation of the end-users has shown to increase acceptance and support to infrastructure projects (Devine-Wright, P., 2011).

Having in mind the challenging economic situation in Greece, special attention should be paid in the issue of the policy instruments that have been used in the past for increasing the penetration of the RES, the feed-in tariffs. These are fixed electricity prices that are paid to renewable energy producers for each unit of energy produced and injected into the electricity grid. The payment of the feed-in tariffs is guaranteed for a certain period of time that is often related to the economic lifetime of the respective RE project (usually between 15-

25 years) (energypedia.info, n.d.). Even if this instrument is not in use since 2015, the guaranteed period of payment with fixed price will continue until the guaranteed period is over. This is translated in higher prices for the renewable energy produced, that is transferred to the electricity bills of consumers. This extra charge amounts to more than 1 billion € per year (Political/ technical expert Ministry of Environment, 2018). This inflation of the electricity bills contributes to the increase of energy poverty, since many household can't afford the higher prices, and additionally, in increases the public's mistrust towards the RES endeavor.

2.8 Energy communities

In 2018 the ministry of energy introduced the draft Energy Community Act. The act is "enabling citizens, local actors such as municipalities and regions and small and medium-sized local businesses to participate in the energy transition and energy planning through their direct active involvement in energy projects, with priority being given to Renewable Energy Sources and savings projects involving mild environmental interventions" (Ministry of Environment and Energy, 2018).

In this way, citizens and other local actors acquire a dual role as consumers and as energy producers (prosumers). The prerequisite for creating synergies and partnerships between various local actors within the Energy Communities is ultimately to create social consensus as well as to enhance the social acceptance of Renewable Energy Projects.

The innovation in the case of Greece is that the act is defining that the energy community has to be of a nonprofit basis. However, the act is allowing profit-based enterprises in case that more than 50% of the participants are individuals and the community numbers more than 10 participants.

An energy community can produce, sell or consume electric and thermal energy produced from RES, such as wind and photovoltaic projects, or biogas and biomass units. It will also be able to operate in the supply of electricity and gas, install district heating systems and desalination units, and install and manage alternative fuel infrastructure and vehicles (e.g. electric).

This act is enabling the local involvement in energy production and the active participation of local communities, as previously a private company's participation was obligatory in any RES project. Especially in the small islands this act is opening several possibilities that will boost the transition to RES, such as (energypress.gr. 2018):

- A municipality, in cooperation with at least two local businesses, could install a biomass power plant linked with a district heating system.
- A local authority, together with local businesses or residents, could install a photovoltaic-wind park or a small hydropower unit. In the case of an island area with water scarcity, the generated electricity could be able to supply a desalination unit.
- Members local businesses or the local authorities, an energy community on a tourist island could install charging stations and procure electric vehicles for their rental to tourists.

2.9 Environmental impact

One of the most important legal frameworks for the protection of the environment in the EU is the “Natura 2000” framework. It is stretching over 18 % of the EU’s land area and almost 6 % of its marine territory. “Natura 2000 is not a system of strict nature reserves from which all human activities would be excluded. While it includes strictly protected nature reserves, most of the land remains privately owned. The approach to conservation and sustainable use of the Natura 2000 areas is much wider (see figure 12), largely centered on people working with nature rather than against it. However, Member States must ensure that the sites are managed in a sustainable manner, both ecologically and economically” (“Natura 2000 - Environment - European Commission,” n.d.).

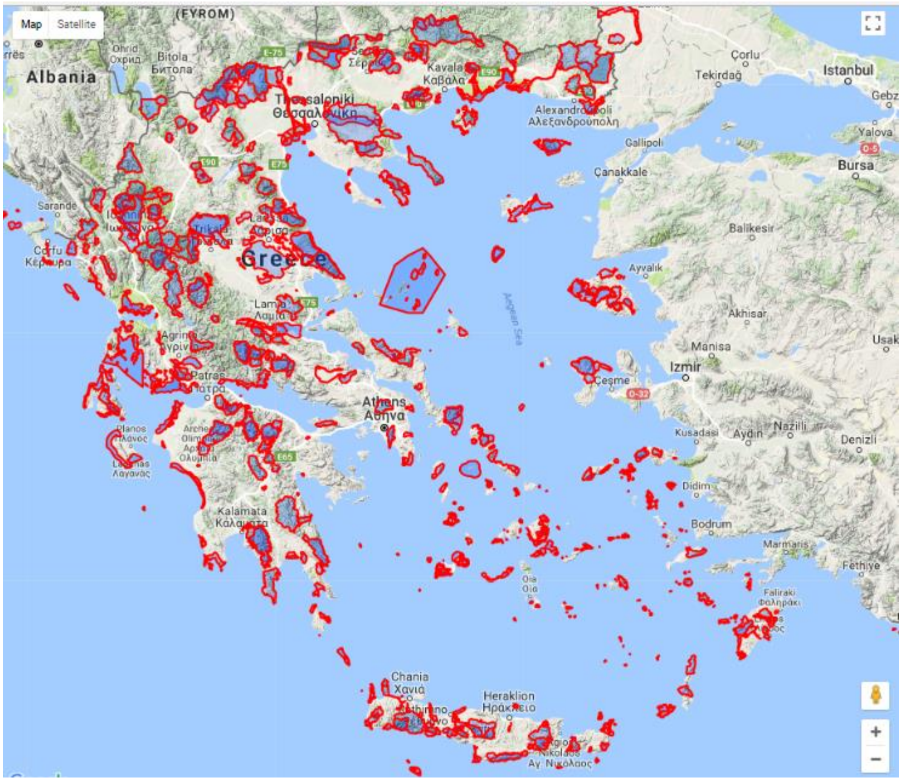

Figure 12:Protected areas under the “Natura 2000” regulation in Greece (source: http://www.geogreece.gr/natura_en.php)

As the rapid development of the recent decades in the area of the Aegean Sea was faster than the regulations for environmental protection, it is obvious that the areas that were not developed for tourism, agriculture or residential use were the ones where the natural conditions were harsh, mostly because of the constant strong wind that dominates the climate. Therefore, these areas became a refuge for any endemic flora and fauna that were pushed out of their native areas due to the human developmental actions. The regulatory framework of Natura 2000 was implemented after the major developmental push that the country experiences in the 1970s and 1980s but still confirmed the fact of the harsh, windy areas being the ones with high presence of wildlife and rich biodiversity. As demonstrated in figures 7 and 12, the areas with high wind potential and the protected areas overlap in most of the cases. This fact makes the deployment of RES projects, especially wind farms, even more challenging in terms of environmental impact, licensing, landscape alternation and public acceptance, to name a few.

Several studies have been conducted on the impact RES projects have on the environment; most of the studies focus on the wind turbines because of their considerable size and spatial requirements. A short summary of the effects is as below:

- Aesthetic effect

The aesthetic effect is one of the most complicated issues since it is largely subjective. A modern windmill can be regarded as "a graceful kinetic sculpture" or "visually awful" in a previously beautiful landscape (Arup, 2015). In any case, since the most common and most visual RES installations are the wind farms, their major size makes it very difficult to ignore during the day and even during dark they remain visible due to their blinking air safety lights. This is becoming more challenging as the size of wind turbines is increasing; an 8 MW wind turbine is more than 220m high (see fig. 13). An obvious solution, that is included in the current legal framework, is to avoid installation in areas of recognized highly aesthetic value, such as landmarks, natural landscapes or areas visible from long distances. This prerequisite remains a friction point as the more isolated and invisible a RES installation is the costlier is to install and operate.

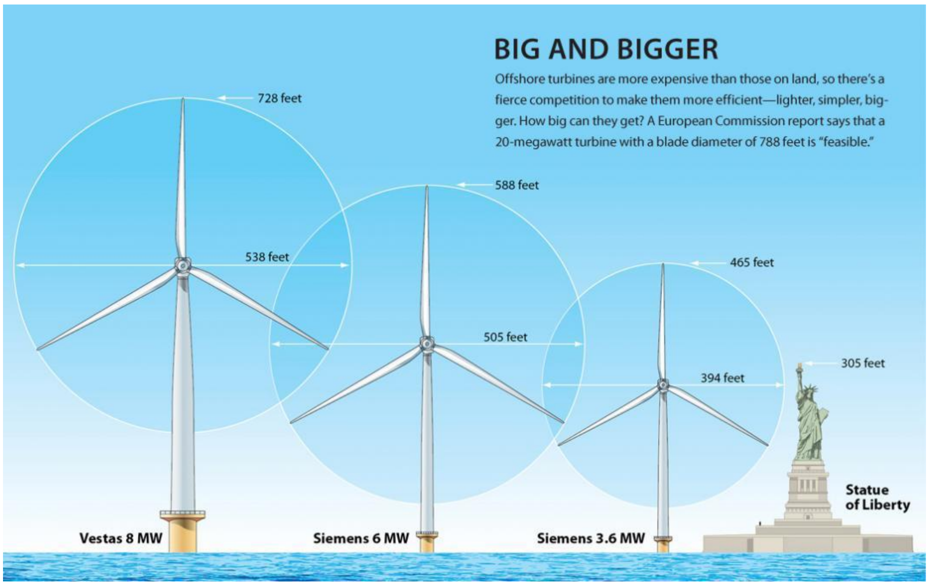

Figure 13: Comparative size of wind turbines (source: D. Kanellopoulos Lectures, Hellenic International University)

- Noise pollution

Noise from wind turbines is generated from the gear box and from the aerodynamic rotation of the blades. The noise level depends to the distance from the source and varies from 100dB on the source to the level of 40-50 dB in a distance of 500m. (see fig. 14) Given the fact that there is no wind turbines allowed in less than 300 m from wind turbines, this makes the expected noise level at approximately 45- 50 dB in the closest residential area.

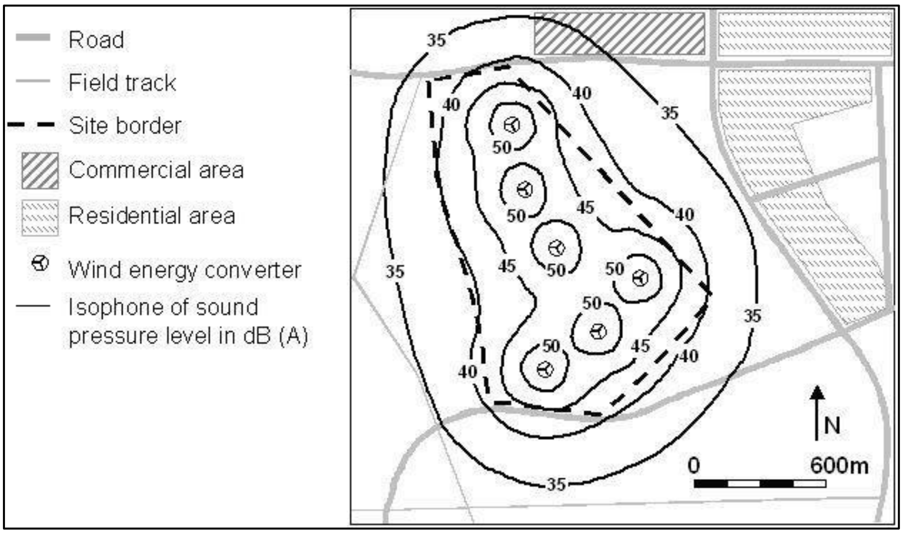

Figure 14: example of the sound pressure level estimations from a 6 wind turbines wind farm (source: D. Kanellopoulos Lectures, Hellenic International University)

- Shadow flicker

Shadow flicker is the flickering effect caused when rotating wind turbine blades periodically cast shadows through constrained openings such as the windows of neighboring properties (see Fig. 15). One of the main concerns is that the flickering effect can trigger epileptic seizures, even if there is a debate on the frequency that can cause a seizure (5-30 Hz flickering frequency is linked with seizures versus the 0,6 to 1 Hz flickering caused by the wind turbines). In some cases when wind power projects are being considered for permitting, concerns are raised that turbine-related shadow flicker has the potential to cause nausea, dizziness, and disorientation. Proponents of wind power argue that the empirical evidence does not support these assertions (Priestley & HILL, n.d.)

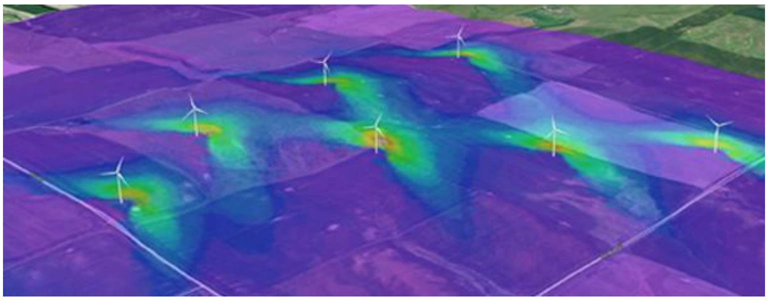

Figure 15: Shadow flicker effect in wind turbines (source: D. Kanellopoulos Lectures, Hellenic International University)

- Impact on flora and fauna

RES projects and especially wind farms require space in wind exposed locations, such as mountains or hilltops. Prior to the installation, roads have to be constructed, sides of hills have to be leveled and, for the base ground of the turbines, large quantities of concrete foundation need to be laid. All these activities affect the flora and fauna, and the biodiversity of the area. Arguments presented by environmentalists claim that the pre-installation mentioned activities cause ecosystem disruption. That consists of isolating the wind farm area from the rest of the ecosystem, making them vulnerable to any supplementary human activity. On the other hand, there are many considerations on the effect of wind turbines on endemic and migratory birds. Birds can collide with the rotor blades, even if their movement is slow (the speed at the tips can reach 200Km/h). It has also been found that migratory birds are more vulnerable to accidents with wind turbine blades (Langston, Pullan, & Europe, 2004), as the bird's flyways depend on the weather condition and are not easily reoriented. The number of birds-hits by wind turbines blades varies between 0-30 collisions per turbine per year (Kuvlesky et al., 2007) . But according to (Edkins, 2014), it is more than 60 dead birds/ turbine/ year.

Solutions have been proposed, such as radars that can detect incoming bird flocks and pause the turbine movement, or scheduled maintenance of the wind farms during the migratory birds passage periods(PPC Renewables executive, 2018). In any case, the environmental impact of RES installations remains on the frontline of opposition against RES projects.

2.10 Recapitulation

As presented in this charter, the energy and resource situation on the Greek islands is, currently, in a transitional phase. Shifting from a fossil fuel-based energy generation to a renewable source one is an endeavor with many critical elements as presented in the sub-charters above. The current approach towards this shift is the market-driven investments, focusing on harvesting the wind and solar potential of the islands. In this sense, the planning for this transition is going to produce a big energy output that is going to get close to the nominal energy needs of the islands in the next decades. The interconnection between the smaller islands remains a bottleneck, as without it the profit potential is nullified by the small market size of the energy demand in these small islands. At the same time, the local societies appear to be rather cautious to a large-scale exploitation because of the potential damage this would cause to the environment and the landscape than subsequently to the touristic product. There is a large number of more holistic approaches to renewable energy sources and can be applicable in the small islands due to their specificities as closed systems; these approaches require the participation of the local societies as well as the implementation of the circular economy principles as essential building blocks.

3. The islands

3.1 Anafi

3.1.1 Current situation & future planning

Anafi (36.36°N, 25.77°E) is a small island in the Aegean sea, in the prefecture of Cyclades. It has a surface area of 40,37 km^2, 38 km of coastline and the population is 271, according to the statistics authority census (2011). However, as in all the islands, the actual numbers are smaller, as in Greece people from the urban centers use to return in the areas of origin during the census period in order to present higher populations number in their native communities. According to locals and the mayor, during the winter time the population varies between 150 and 200. During the summer period however, Anafi's population is significantly increased due to the tourism and the school holiday season; this can lead to a total population of more than 2000 (Iakovos Roussos, 2018) with the total number of visitors for 2012 being 4300.

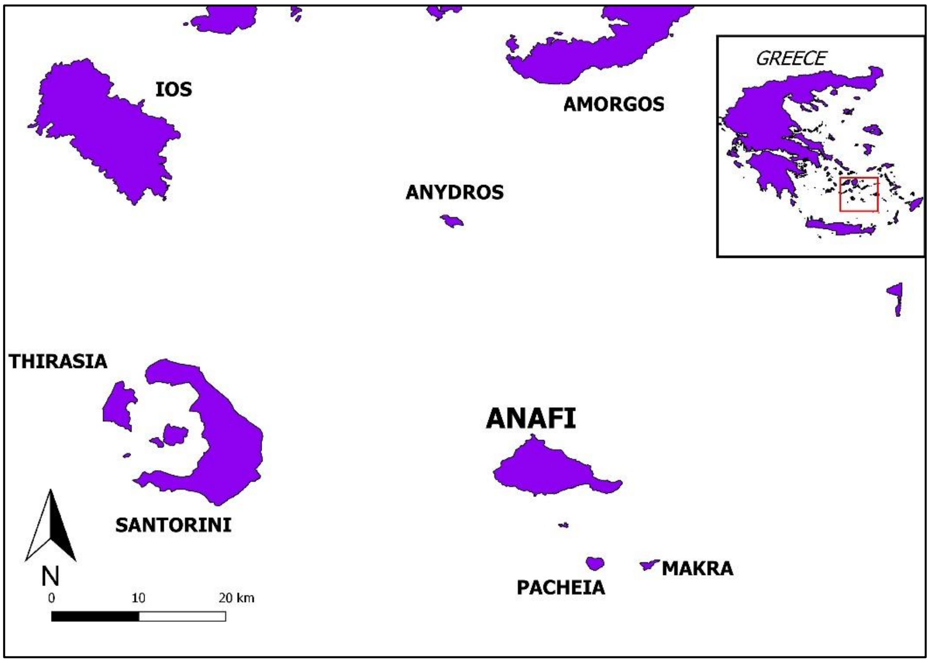

Figure 16: Map of Anafi

Anafi's economy is based on tourism, agriculture, apiculture, fishing and construction- the later linked with the increased demand of touristic accommodation. Almost all families in the island are involved in tourism in some level (Efthimiopoulou D., 2017).

Anafi has significant solar and wind potential. The yearly sum of global irradiation received by photovoltaic modules mounted at optimal angles has been calculated at more than 1800 kWh/m^2 (EU JRC, 2018) As for the wind potential, the average yearly wind speed is around 6m/s with the North-northwest wind as the most dominant (CRES, 2018).

The island is not interconnected with the mainland grid or any other island. Such a connection is a challenging project as has to be done with the major, neighboring island of Santorini, which is also not interconnected, neither is planned to be in the next 5 years. In Santorini there is an autonomous generating station with generating capacity of 22200 kW, which is operating near its limits as the maximum demand during the peak (touristic) season is 22700 kW. The yearly consumption of Santorini is around 67122 MWh ("Hellenic Energy regulatory Agency, 2018).

Figure 17: Anafi Autonomous Power station

In Anafi, electric power is provided by the autonomous generating station, owned by PPC which is located next to the port. The installed production capacity is 355 KW, while the maximum demand is around 340 kW. The yearly consumption is around 600 MWhs. (Hellenic Energy regulatory Agency, 2018). The station is operating without any serious disruption, but since it is the only power source of the island, the operating cost needed to maintain the required reliability is necessarily high.

There has been quite some interest for the installation of RES on the island, especially wind turbines. According the Hellenic regulatory agency, permissions have been issued for installations of wind farms on the island, as well as on the neighboring uninhabited islands of Pachia and Makra, where the initial planning is for major installation of more than 50MW on each (RAE GeoPortal, 2018). However, the issue of interconnection makes this investment quite more challenging than a regular installation on the mainland.

Additionally, the issue of renewables has been researched from potential investors on the island. There has been interest from various actors, most notably the Aegean chamber of commerce and a private energy company named "Cycladika Meltemia" but there is nothing definite in terms of planning at the moment of writing. The project proposed by the commercial chamber of Syros (the prefecture's capital) was aiming at making islands autonomous and was including more islands in the prefecture, such as Amorgos and Serifos. However, after the initial contacts there has been no follow-up (Iakovos Roussos, 2018).

Figure 18:Areas where permission for wind turbine installation has been granted, including Pachia and Makra islands (Source: Hellenic Energy Regulatory Authority)

The proposed plan of the "Cycladika Meltemia" included the installation of a wind farm on the north - west part of island as well as installation of a wind farm in the neighboring, uninhabited islands of Pachia and Makra (see fig. 18). Additionally, there would be an installation of solar parks in both islands as well as battery pack for electricity storage. Excess energy would be used to power the desalination plant of the island. The plan would include the installation of the underwater cable that would connect the wind farms to Santorini.

The municipality has no saying in the energy planning. This is because of its very small size and the lack of any technical capacity. Apart from very few individuals that are skilled, most of the inhabitants are occupied in tourism, traditional occupations such as agriculture or are retired. Therefore, all the initiative for the energy transition is driven by private interest. This is evident from the fact that the municipality has no information on the process of the proposed energy plans from the two main investors. However, the companies involved have provided the municipality with a list of benefits and incentives that they will enjoy in the case that the RES will be installed, such as free electricity in all municipal buildings, reduction of electricity bills, etc., based on the regulatory framework (the 3% of the electricity value that returns to the locality).

The possibility of the island inhabitants becoming partners of the energy company with specific sharing levels was also mentioned, with the proposed participation of the locals based on a company shareholder frame rather than a community-based enterprise. During the time of the interview the legal framework on energy communities was rather new, but the proposal from Syros chamber was including the participation of the locals; having the project funded by subsidies in a major part and also having the municipality and citizens included in volunteer basis (Iakovos Roussos, 2018).

From the part of the municipality, publicly owned areas have been identified for the installations. Therefore, the spatial management with disputed from the landowners should not be a problem.

Regarding the societal response, the population of the island seems to be positive; even if there has not been any organized survey the small size of the population and the even smaller size of the active community members makes it easy to have a picture of the community's position. The main objection would be the installation of the wind farms in the south part of the island where most of the touristic facilities exist, as well as the popular beaches and landmarks of the island. As long as the wind farms are not visible from that areas, there will not be any reaction from the island population. However, since the island touristic character is based on the wilderness, the unspoiled nature and the lack of large infrastructure, it is very possible to have reactions from regular visitors and activist groups on any large-scale wind farm installations. As an example, an illegal earthwork near a popular beach in April 2017 raised a big protest in social media by regular island visitors in less than 24 hours, forcing to mayor to make a press statement (efsyn.gr, 2017).

The environmental impact of RES installation has not been formally assessed. However, there are considerations for the bee population as well as for sea bird population. The protected areas of the island (natura2000) are in the south part of the island therefore there will be no conflict in this case.

Apart from the wind farm investment, there are no major plans on any other RES, such as solar. As Anafi is a rather dry island with limited rainfall level of less than 400mm/ year, the potential for any small hydro plant is very low. Biomass utilization poses challenges, as livestock numbers have been reduced dramatically during the last 30 years; there are currently 120 sheep and goats on the island when there used to be around 10.000. The land used for agriculture is around 2000 acres, while the full potential of the island is around 15.000 acres for agriculture (Efthimiopoulou D., 2017). Utilization of organic waste in the island is also low due to the small number of inhabitants and the high complexity of a possible collection system. These factors are limiting the biomass potential.

3.2 Nisyros

3.2.1 Current situation

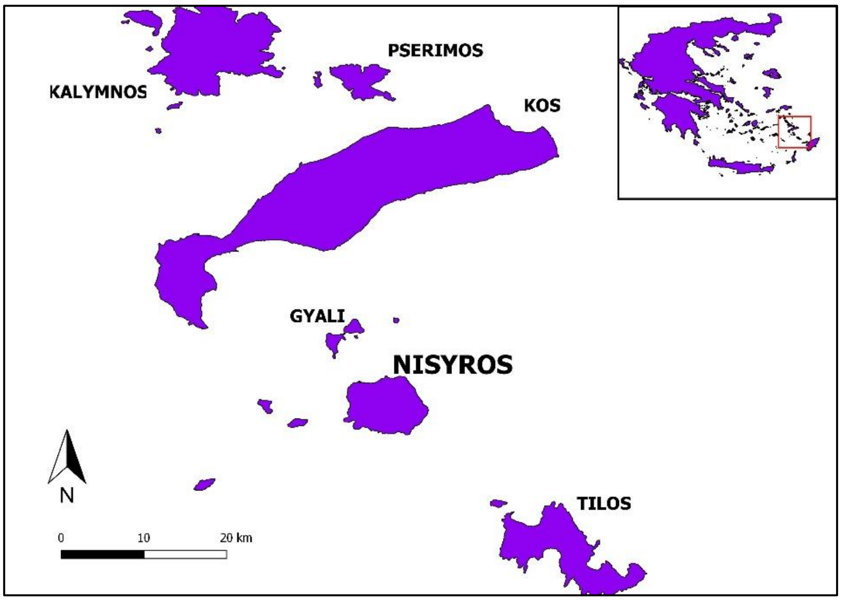

Figure 19: Map of Nisyros

Nisyros (36.58°N, 27.17°E is a volcanic island situated in the south east Aegean sea, in the prefecture of Dodecanese. It has a total area 50,06 km^2 and the population is 1008 according to 2011 census. It is situated 11 miles south of Kos, which is the main transportation and communication hub of the area, having a major port and an international airport.

Nisyros is interconnected with Kos throuh an underwater cable of 20kV, forming a cluster that consists of Tilos, Kalymnos, Kos, Leros, Pserimos, Telendos and Gyali. The total installed power that electrifies these islands is 69600 kW, with maximum demand around 59300 kW. The annual consumption for all island cluster is 217824 MWh. The country energy planning foresees the connection of this island cluster with the mainland at 2022. Before the island interconnection, Nisyros was powered by an autonomous station of 700kW, which is now not in use, but is operational as a backup (Hellenic Energy regulatory Agency, 2018).

There is no usage of any RES in Nisyros right now, except the use of solar water heaters in individual household level (Christofis Koroneos, 2018). All needed energy is provided through the connection with Kos. However, Nisyros has been present in the Greek renewable energy map as it is one of the islands with the highest geothermal potential in the country. In the same sense, Nisyros has been a ground of confrontation between local society and the centralized energy planning of the country regarding the utilization of its geothermal potential.

3.2.2 The case of Nisyros geothermal potential

Nisyros island is considered a “sleeping” volcano (see fig. 20). The last volcanic activity occurred several thousand years ago and is not mentioned in any historical sources. The last magmatic action in the area of Nisyros occurs about 20,000 years ago, and there is some evidence that the latest explosion in the neighboring Gyali island is probably less than 10,000 years old (Municipality of Nisyros official web page, n.d.)


Figure 20: Nisyros volcano area

Geological investigations for the geothermic potential began in 1973, including nine exploratory drills of 70m depth within the volcano caldera. The first evidence revealed the region's extreme thermal potential reaches up to 20 times the average potential in other locations.

The first conclusions that emerged from the analysis of

the Nisyros field were that the island presents geologically favorable conditions to its geothermal economic exploitation. The assessment was based on the constant existence of a heat source (magmatic chamber), the vertical permeability of the geological formations in the caldera, the water vapor barrier cover and the appropriate water permeable formations was in economically advantageous depths. From these conclusions it emerged that Nisyros geothermal potential is of the order of 40-50MW. Given the island's energy needs (1-2MW), it is possible to power the neighboring island complex that includes Kos, Tilos, Kalymnos and Leros.
Subsequent deep drilling drills at 2000m depth revealed a high enthalpy reservoir (usable for energy production) inside the caldera. The geothermal implementation scenario provided for the installation of two 5MW units each. Based on the environmental impact study, PPC proposed a setting of five wells and a 10MW facility that could be constructed in the uninhabited southern part of the island, being environmentally acceptable and economically advantageous (Nisyrian studies Society, n.d.).

The local society objected the proposed plan based on environmental concerns on the danger of installing such a major unit in an island the size of Nisyros. More specifically:

- The small size of the geothermal field and the mountainous landscape
- The lack of experience in installations in similar settings
- Insufficient legal frames for the environmental impact, such as the concentration of heavy metals pollution in the land and the sea
- Non-sufficient knowledge in the effect this installation will have in the seismic activity of the area
- Problems occurring in a similar installation in neighboring area in Turkey, harvesting the same geothermal field
- Disproportionate size of the project yield compared to the small size and needs of Nisyros

Based on the above, the alternative option coming from the society is for utilization of a smaller yield factory, based on low enthalpy harvesting (30-100ºC) of a maximum yield of 2 MW for use in heating (domestic and greenhouses) and cooling (Christofis Koroneos, 2018; Nisyrian studies Society, n.d.). According to Nisyros municipality, any concept that exceeds the needs of the island in energy generation will not be accepted. “Nisyros is not going to become an electricity generating factory” (Christofis Koroneos, 2018)

3.2.3. Energy planning, circularity

The energy planning of the island has a 5-year horizon and aspires to have the island energy neutral by 2023. The electricity is planned to be generated by one solar park of 500KW capacity and 2 wind turbines of total power of 2 MW. This level of generation capacity can cover the entire needs of the island. The estimated cost of this project is at 22-23 million euro. The existing diesel-based generator will remain as backup and will gradually be converted to a natural gas one. All RES installation will be deployed in publicly owned land (Nikolopoulos N., Sfakianakis A., n.d.).
The technical support for the design, planning and implementation of the project is delegated to the technical services of the ministry of finance, as the municipality of Nisyros lacks the technical expertise for a project of this size and specialization. The technical support to the municipality is also provided by other governmental agencies for the implementation of the RES project from a large number of agencies, as there are several requirements for the licensing.
According to the mayor, the main bottleneck is the lack of strategic planning in the nation level. This fact is making proper long term planning in the local level challenging and therefore prevents institutional funding can be made available through EU subsidies that could be available for RES projects in settings like the one of Nisyros (Christofis Koroneos, 2018).

Circularity concepts are present in the island. There is a conference that is held every 2 years on "Exergy, Life cycle assessment and sustainability" on Nisyros with several academics attending (5th ELCAS, 2017). Additionally, Nisyros municipality is one of the key actors in the discussion on circularity in the islands. "The goal is to be able to change the way we produce and consume products. With sustainable management and use, we move from the linear economy to a cyclical economy that means easy recycling, renewable resources, eco-friendly products, less environmental impact, changing the mindset of the world" (Christofis Koroneos, 2018). The main focus of the municipality is to increase the level of recycling on the island, sensitization and education activities in the community (such as the free distribution of fabric shopping bags to replace the plastic ones).

3.3 Tilos

3.3.1 Current situation & future planning

Tilos (36.43°N, 27.36°E) is a small island in the Aegean Sea and is part of the Dodecanese islands group. It lies between Kos and Rhodes. The population is 780 inhabitants (2011 census). The total area of Tilos is 64,5 km^2.

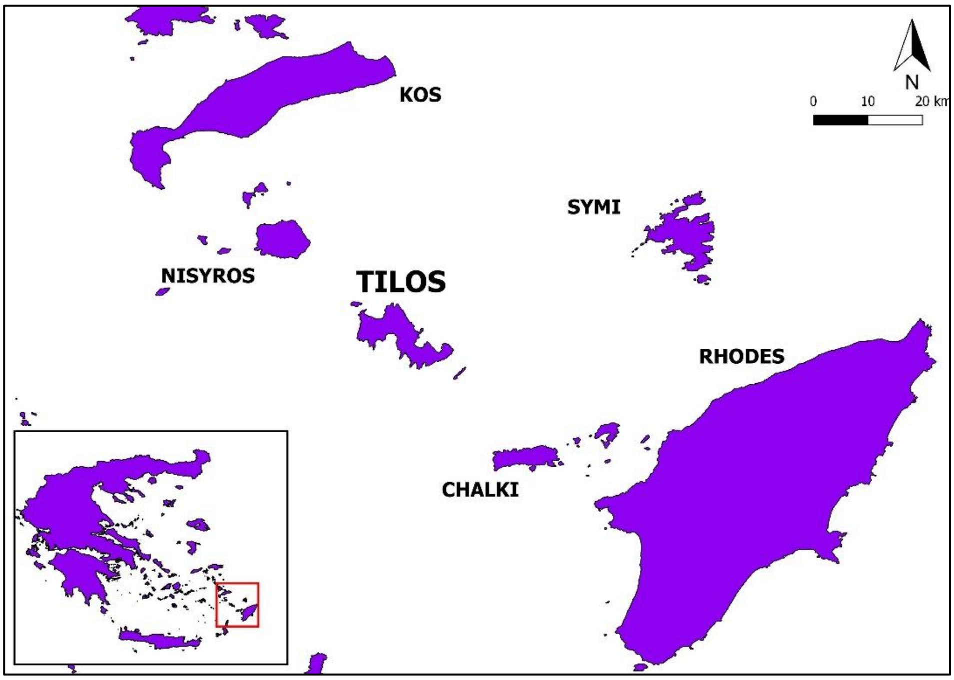

Figure 21: Map of Tilos

Tilos has a long history of environmental initiatives; hunting was completely forbidden in 1993, before any other island in Greece, eco-tourism was encouraged by the municipality, networks of foot paths were cleaned and marked, and community initiatives are common. The municipality's plan includes a small recycling unit, a holiday eco-village, bio-product processing unit, etc. The whole island and the neighboring islets are in a nature protected status, which was promoted by a locally run NGO, named "Tilos Park", where 2/3 of the islanders are members ("Tilos Park Journal," n.d.).

Tilos also aspires to become the first energy neutral island in Greece. This is implemented by the project "TILOS", aiming at maximum coverage of the electricity needs of the island through RES.

The project's main goal is to demonstrate the potential of local / small-scale battery storage to serve a multipurpose role within an island microgrid that also interacts with a main electricity network. Among others, the project aims to achieve large-scale RES penetration and asset value maximization through the optimum integration of a hybrid RES (wind and solar) power station together with advanced battery storage, distributed, domestic heat storage, smart metering and Demand Site Management.

This is achieved with hybrid energy production system, consisting of a wind turbine of 800kW, a small solar park of 160kW and a battery storage system with capacity of 2,4GWh, in the same location as the wind turbine (see fig. 19 and 20). Additionally, the system includes smart electricity meters installed in the households and municipal buildings and a smart energy management system that aims at maximum energy self-sufficiency by balancing the demand and production including the batteries). The project has completed all the infrastructure phase and is currently being tested. It is expected to be operational by January 2019 (TILOS Horizon, 2018.).

Figure 19:The solar park in Tilos

Since Tilos is interconnected with the cluster of Kos and more islands, when referring to self- sufficiency it describes a neutral energy balance, rather than a produce- consume scheme. According to the project design, Tilos will be able to meet all energy needs, and even export energy to the Kos grid.

There are several partners for TILOS project. It engages 13 participating enterprises and institutes from 7 European countries. These include the municipality, the transmission network operator (HEDNO), Universities, the World Wide Fund for Nature and private companies, as the EU regulations require participation of private companies a prerequisite for any funding.

The wind turbine and the solar panels are installed by EUNICE, which is the private sector partner of the project. That's because the project was funded by EU but with the obligation to have also a private company as a partner. EUNICE has invested around 2,5 million euro and has installed all the infrastructure related parts, like the panels and the wind turbine. The wind turbine generating capacity is 0,8 MW, while the island energy needs are around 1,1 MW. The estimation is that the production will reach 1,2 MW so there will be electricity exported to the grid.

Figure 20:The wind turbine and battery installation in Tilos

The TILOS project was initiated and was led by the technical university of Piraeus in Athens, which produced the original concept and all the planning, including the technical and financial analysis. The whole project proposal was presented to Tilos municipality and, after the acceptance of the project, decided to proceed with implementation through providing municipal space for the installation and providing all support needed (SEALAB, 2018). During the whole process there was no collaboration with any of the government branches, except from the electricity transmission operator (IPTO). Before the initiation of the project as island residents participated in information meetings, where the technical and operational aspect of the projects were presented, the new tools to be used were presented (smart meters, PDAs) and extensive consultation and discussion were held. A main point was the trust building with the community, which was based on giving specific indicators and dates for the project stages that could easily be verified by the residents (Stathis Kontos, 2018).

During the implementation phase of the project there have been two environmental impact assessments, since the whole island falls under the natura 2000 protection – it is the only island in the Mediterranean that is entirely under its protection. The position for the wind turbine installation has been relocated from the initial area, based on consideration on the impact it would have on a falcon endemic species. However, the current location raised some objections from residents, because of the proximity of the turbine to one of the popular beaches of the island. This objection focused on the aesthetic degradation that the wind turbine would bring; the project planning includes major landscaping activities to minimize the impact.

Effects on the fauna of the island were also considered during the EIA; the main population of large predatory birds is located further south from the wind turbine location

The financial impact this project will have is not possible to be estimated before the installations are operational and connected to the grid. Nevertheless, the additional island and community benefits extend to several points (Stathis Kontos, 2018):

- The electricity quality of the island will be improved; even if the main energy provision is done by the underwater cable, there are frequent power cut—offs, with significant impact to the island businesses (especially during the summer period with the food storage relying on refrigerators)
- The “Tilos” project gave a positive publicity of the island. Tilos is now considered to be one of the first energy -neutral island s in a global scale. This publicity benefits the touristic industry and defines the island as an eco- tourism destination, increasing their traditionally “green” and progressive image, which makes the island stand out from the other competitive islands in the region.
- The issue of responsibility and supporting the national goals towards increasing the participation of RES and on reduction of CO_2 emissions
- Sensitization of the community on environmental issues. The Tilos project increased the participation in recycling and the circular economy discussions in community level.
- This active participation of the municipality in the whole project is one of the particularities of this project; it acted beneficially to the credibility and prestige of the project, as well as for the municipality itself.

The circularity potential of the island revolves around the main economic activities of the island, which is the touristic and primary production sectors, since Tilos has a large agricultural capacity and potential. The municipality would focus on the agricultural production initiatives, such as goat cheese making, or honey, as they would like to balance the primary sector incomes with the ones from the tourism sector. Their plan is to form a cooperation that will have livestock farmers and the refugees that have been granted asylum in the island that will produce products and, in the same time initiate symbiosis activities. Another activity is to have canning and sugar preservation artisanship in order to minimize agricultural waste during the low touristic season (Stathis Kontos, 2018). Currently there are no plans of utilization of organic waste for biogas production.

3.4 Recapitulation

The three islands researched present a characteristic sample of the various stages of renewable energy integration. Anafi is an island without any renewable energy implementation, autonomous and can be considered as a "tabula rasa" for the energy transition. It is entirely dependent on the private interest for initiatives on the renewable energy sources, as its extremely small size is making it challenging to initiate anything that is community driven. Nisyros on the other hand, has a plan making the island energy neutral and circular, but presents a strong paradigm of the conflicts that can occur between the society and the RES planning; a conflict that has delayed the transition considerably and reduced the trust levels towards RES in the society. Tilos has been in the frontline for the transition in a global scale. Having the driving initiative from the academic world, while being already a very "green"- oriented island, contributed towards Tilos becoming the first energy neutral island in the Mediterranean. However, the social integration of this endeavor remains the main challenge, as well as using Tilos achievement as a step towards an integrated circular economy approach that will combine the primary sector, tourism and renewable energy.

4. Analysis

After looking into the current situation of the islands, we can categorize the factors that affect the situation of RES in external and internal.

We can define as external context all the factors that are not related to the specific islands context. This involves the general context of the country, such as the legal framework, both in the EU and Greece, the technical possibilities and limitations, the funding schemes, the potential of different technical approaches, etc.

The internal contextual factors are the ones specifically applying to the small islands as they were defined in the research framework. Factors can include the administrative status of the islands (being autonomous municipalities), the touristic economy levels, the electricity interconnection status, the societal response, the level of initiative of the community, etc.

The interaction of these two groups can highlight the points that can accelerate the implementation of RES in the islands, as well as the community involvement in these endeavors.

4.1 External contextual factors

Technical factors

When discussing about the transition from fossil-based energy generation to a RES based one, the technical challenges and factors to be considered are several. These challenges pose one of the main bottlenecks in the integration of RES in the islands as well:

1. The interconnection of the islands is the factor that is defining the technical approach that will be adapted when a RES project is designed. Since RES have a fluctuated output of energy, the supply and demand balance is a technical challenge. This becomes even more crucial in the cases on non-interconnected islands, where the reliability of the electricity supply is crucial for the economy, especially during the high-demand, touristic season. Therefore, a completely different approach design is required. Islands like Nisyros and Tilos that are already interconnected can have the RES installations as their main electricity sources and at the same time any surplus or shortage of supply can be equalized from the grid. A different technical approach is required in the non-interconnected islands, such as Anafi, as the whole setting has to have the potential to cover the

needs of the island in the case that there is no wind or no sunshine. For this case, the existing fossil fuel-based generator has to remain operational to a certain extend.

2. The underwater cables that make the interconnection of the islands technically possible. This endeavor is a major investment in terms of technical complexity and cost, therefore is a part of the long term strategic planning of the country, as seen in the overview of the interconnection of the islands in Greece.
3. The rapid development of new technology can make an installation rapidly obsolete and financially not viable without governmental subsidies. This is evident in the technology of the wind turbines and photovoltaic cells that are constantly becoming more efficient and cheaper. Therefore, an investment can become less profitable in a shorter period than expected, and this is evident from most of investment in the islands being on wind parks rather than any other form of RES.
4. Unpredictability of RES supply (lack of sunshine or wind) require installation of combination of approaches, such as solar and wind, which is the most common setting as seen in most of the cases of RES installations. More stable RES technologies such as geothermal, hydro and biomass/ biogas installations have not been prioritized in the energy planning of the islands, based on the abovementioned investment limitations.

Financial factors

1. The majority of funding is private
2. Large subsidies (feed -in tariffs) are not any more provided
3. Basing the funding of a project on governmental subsidies requires an innovative approach, such as the one of Tilos
4. Municipalities are receiving 3% of the profit
5. High initial cost for installing RES
6. Wind harvesting is the technology that is preferred by private investors as it has the shortest cost recovery period and the highest profit potential

Political and legal factors

1. Different priorities of governments. As mentioned from all the interviewees, the lack of central planning is making the whole transition to a RES based energy generation in the country and specifically to the islands fragmented.
2. Priority in the private initiative. The case of Tilos is the only one where a non-profit stakeholder initiated a whole project for RES. Therefore, a more holistic approach on the RES was followed with the close collaboration of the municipality. In the case of Anafi, the whole transition to RES is entirely led by private interest, while in Nisyros the scheme to be followed remains to be finalized.
3. New framework for energy communities. The new act gives sufficient tools for local initiatives for energy production. Even if in principle an energy community can be a collection of a number of interests, the possibilities that the act opens for local, community-based initiatives is increasing opportunities for a more integrated RES approach, that will include circularity principles such as the symbiosis between primary production and energy generation (e.g. biomass collection or heat recovery)

4.2 Internal contextual factors

Societal response

The societal response in the islands researched varies. In Anafi there is minimal involvement of the community in the energy planning and the technical solutions chosen, while Tilos has a different approach with plenty of community involvement. Nisyros societal response is closely tied with the conflict of the geothermal potential, which polarized the local society greatly.

Touristic potential

A common characteristic of all small islands researched is the dependency of the economy on tourism. The second element is that the nature of these islands is not favoring a large scale, luxury tourism, but a mild, eco-friendly, eco oriented touristic approach. Therefore, activities towards RES implementation and circular economy have a great opportunity to be integrated into the touristic "product" the island is offering, as observed in the island of Tilos.

Size of the islands

Islands in the Aegean are in the center of the current wind harvesting planning. The installation of large scale wind farms can greatly affect the landscape and alter the land use, leading the sensitive local economy into a turmoil.

Self-sufficiency vs export

A question that rose in all the three islands researched was about the size of the installation. Most of the islands authorities insist on production capacities that can cover the demand of the (interconnected) island and refuse to have any additional capacity installed (PPC Renewables executive, 2018, Christofis Koroneos, 2018).

Financial benefits

The current financial benefits of a municipality, which is now 3% of the value of the electricity produced, is certainly an incentive. In the case of st. George island, the neighboring municipality's benefit was around 500.000€ (energypress.gr. 2018), which is a major addition to the island's budget. Islands like Anafi can expect similar benefit level if the major installations in the uninhabited islands in their vicinity proceeds.

Community participation

Participation of the communities in the RES projects remains quite low. Only in Tilos there is a level of participation and this is in the form of becoming a stakeholder in the investment. In Anafi, the theoretical possibility of participating in the RES investment was raised by the potential main investor, but the implementation stage of the project makes this option too premature to be evaluated.

4.3 Interaction points

From the above factors, different thematics can be grouped and form several interaction points that can lead to conclusions:

1. The cost recovery period and profit potential are leading to RES investments that are overwhelmingly wind harvesting oriented.
2. Wind farms have significant impact in the land use and the aesthetics of the small islands that can affect the natural character of the islands and lead to societal reactions.
3. The touristic character of the islands and the size of any RES project: Installation of large wind farms in islands that have a wild, virgin characteristic will alter the landscape and the final touristic product.
4. One of than main challenges of initiating a RES project is the initial funding, that is in the level of 1-1,2 million euro / MW of a wind park, while the cost recovery is around 8-10 years (PPC Renewables

executive, 2018). Funds of this volume can be made available from private investors but not from municipalities.

5. The profit driven transition to RES in the islands is focusing on electricity generation and deprioritizes other uses of RES that can only be developed by communal initiatives and governmental funding.
6. Any investment in RES projects is limited by the interconnection of the specific island with the grid, as the technological approach is completely different if there is no interconnection.
7. RES technologies not entirely focusing on electricity generation have several uses that promote community participation and encourage symbiosis in the primary production level, thus increasing circularity in the islands
8. Similar with point 7, this milder RES approach can be integrated into the touristic potential in the specific islands that are already classified as quiet, eco-tourism destinations. This kind of integration will interact with the social acceptance.
9. Financial returns to the communities by the investor is limited to the 3%, which is centrally managed and not properly monitored neither regularly attributed to the communities.
10. Apart from the 3% return there is no standardized corporate social responsibility[1] activities that are linked with the communities other than “providing jobs” and “making Greece greener”

4.4 RES penetration from a common pool resources point of view

A second analytical approach could be attempted, through the comparison of the design principles for achieving institutional robustness in Common pool resources, as they defined by (Ostrom, 1990) and presented in charter 2.5), and the actual situation in the three islands researched.

1. Clearly defined boundaries

When referring to the Greek islands or mainland, RES projects are usually initiated by a company - a consortium of stakeholders that usually involve the municipality as a secondary partner. By secondary, we define the part of the involvement that is limited to supporting the project by administrative permissions and spatial facilitation, as observed in the islands of Nisyros and Anafi. In the case of Tilos, the project was initiated by an academic institution, therefore was non- profit driven and the participation of the municipality was an active one. In natural resource systems the resource is a physical input, however, for energy, the resource is more like a *process* or *activity* which results in an outcome. In this sense, the boundaries are currently clearly defined.

2. Congruence between appropriation and provision rules and local conditions

Appropriation rules restricting time, place, technology, and/ or quality of resource units are related to local conditions and to provision rules requiring labor, material, and/ or money. In this sense, we can include the debate of the size of the RES installation projects, as restrictions to time and place of technology. The debate of the size and technology of the Nisyros geothermal potential harvesting can be viewed as an imbalance between provision rules and local conditions. In Anafi, the same imbalance is present, however the local conditions can be more adaptive on the disproportionate harvesting of the wind potential, compensating with the financial benefits that will occur.

[1] Corporate social responsibility (CSR) is a business approach that contributes to sustainable development by delivering economic, social and environmental benefits for all stakeholders.
CSR is a concept with many definitions and practices. The way it is understood and implemented differs greatly for each company and country. Moreover, CSR is a very broad concept that addresses many and various topics such as human rights, corporate governance, health and safety, environmental effects, working conditions and contribution to economic development. Whatever the definition is, the purpose of CSR is to drive change towards sustainability (Financial Times Lexicon, n.d.)

3. Collective-choice agreements

This principle is not met in the islands researched, as the residents of an island that will be de-facto affected by a RES installation are only represented by their municipality. The engagement of the community is important in the determination of the arrangements that will keep the RES projects relevant to them as end users. Participation of the community (as mentioned in charter 2.7) has shown to increase the acceptance and the support for such projects.

4. Monitoring

Only in Tilos there is a provision monitoring the condition of the RES as CPR. This is achieved by the technical innovation of installation of smart meters in all connections, as well as the distribution of handheld computer terminals (PDA) that present the production and consumption of energy in the household and the whole island level. In the other two islands, there is no provision for the actual monitoring. Theoretically the municipality could have access to the data of the grid and have an overview, but this is far from the level where the appropriators have a clear picture of the actual production. This is becoming even more problematic, as one of the main incentives for the communities and municipalities is the amount of 3% of the total income of the RES installation that is conveyed back to the municipality where the production is based. This is split in 1,3% for the municipality administration and 1,7% for the citizens. It is evident that without clear monitoring and transparency, this aspect can lead to a breach of trust between parties.

This is mostly due to the fact that the process of this return is centralized (PPC Renewables executive, 2018), and the crediting of the local accounts is not regular. This is a common problem in the Greek public administration where cash flow challenges create with irregular payments and long delays from the central state cashier to citizens and public agencies. In the case of Tilos, at least there is a clear accounting status, but in the other two cases the lack of proper monitoring can lead to collapse of trust and accusations of corruption. Especially when the profit from an off-shore park can reach large amounts of revenue (as in the case of st. George island), which is a disproportionately large, compared to the budget of a municipality of 250-100 people. In relation with the issues of lack of trust, this is a rather serious challenge.

5. Graduated sanctions

In none of the islands researched there is any special or customized mechanism for the small islands for sanctions in cases of any violations. All conflicts are resolved within the existing legal frame.

6. Conflict resolution mechanisms

There is no specific conflict resolution mechanism for the specific RES projects. Since there is a high complexity in the stakeholders and institutional settings in each island, any conflict will be resolved by direct negotiation or by the existing legal frame. The lack of this kind of mechanisms can be a source of negative situations or long delays in the case that a conflict will need to be resolved by the time consuming legal system.

7. Minimal recognition of right to organize

The right to organize is present, after the introduction of the energy community act. However, the short period since the introduction of the law has still not been sufficient to witness the implementation of this policy in a small community level. The case of Tilos is quite close to a self-organizing model where the right to organize is stressed through municipal initiatives

8. Nested enterprises

Similar with the previous design principles, the institutional vessel for appropriation and provision rules, monitoring, conflict resolution, etc., should ideally be an enterprise formed by the communities, since the size and the framed nature of an island is benefiting this setting. As mentioned in charter 2.7, a legal entity of an energy community in the islands, as end users and producers would be the most appropriate approach. Still, the short period of time from the introduction of this setting is not allowing any conclusions at the present time.

4.5 Recapitulation

After analyzing the situation in the islands based on the two approaches we can summarize, attempting to outline certain criteria that could define the effective implementation of utilization of Renewable Energy Sources and the principles of circular economy in the small islands. This summary can be compiled into five criteria:

1. ***Level and nature of partnership of the private investors and the municipality/ community for implementation of the RES project in all its stages***

As discussed above, shifting to RES should be considered as an opportunity towards a holistic approach to energy use, circular economy and sustainability. In this ambitious endeavor participation of all stakeholders is essential for an effective outcome. And this participation can be summarized in the sustainability approach of "People, Planet, Profit". Any major imbalance from this scheme, can lead to an implementation that is fragmented. This is evident after applying the Common Pool Resources principles in the cases of the islands that were examined: the collective choice agreements, the minimum right to organize, monitoring and the nested enterprises.
High levels of interaction and participation of the community and the private investors were observed in the case of Tilos which presents a successful case. In the other islands the levels of partnerships are low. In Nisyros the lack of a common platform between stakeholders on defining the nature of the geothermal project led to conflicts and implications. Finally, in the part of "community", the organizations of civil society as well as the academic community can be included.

2. ***Level of acceptance of the island society on the RES implementation***

Unlike the criterion 1, where the participation of the community is expressed in a form of partnership, the acceptance of the community in the whole project is vital for any development. As observed in many cases in the world and Greece, the community can halt any projects that are contested; even if the community's objections don't have strong arguments. The case of Nisyros and the approach of the geothermal potential provides a good example in this criterion.

3. ***Level and nature of participation of different RES in the total energy quota***

A vertical approach towards RES, focusing only on electricity generation (having the fastest cost recovery period) is an approach that does not favor the sustainability of the RES penetration in the culture and character of the islands. With increased diversity of RES utilized, more environmental friendly technologies can be implanted, with larger life cycles and are closer to the circular economy principles

4. ***Level of integration of a nexus between RES, economical activities, tourism and circular economy in the islands***

As discussed above, the shift to a RES based energy generation presents an unprecedented opportunity for the introduction of circular economy in the small islands, an opportunity that is amplified by the small and closed nature of these islands. This opportunity consists on:

a. the availability of funds that can be available through the 3% of the electricity produces as well as the possible contributions through CSR of the investor
b. the momentum of the energy production shift to implement innovative projects, such as the ones in Tilos were the primary production is linked with the RES or the case of Nisyros with the utilization of geothermic energy in greenhouses.
c. the global demand for eco-friendly touristic destinations

These 3 elements are in line with the ReSOVLE approach, as presented in charter 2.5, and more specifically with the *Regenerate*, *Optimize* and *Loop* action points (see table 3 and fig. 8).

5. ***Level of landscape alternation and environmental impact of the RES implementation***

The impact of RES in the landscape and the environments, as presented in charter 2, can be one serious obstacle on the integration of RES. As also analyzed in charter 4, one of the key elements in managing this challenge is the implementation of proportionality in the RES projects; this is strongly lined with the rest of the criteria, as a mild integration of the RES in a small island economy is linked with the diversity of the RES that are harvested, as well as the analogy between the size of the island and the energy produced. Finally, the adaptation of the communities to the aesthetic effects, as well as the adjustment of the flora and fauna to the RES projects, require this mild approach.

5. Conclusions

Islands in Greece enjoy favorable conditions for utilizing renewable energy from various sources, such as the wind, the sun or the geothermic energy. Additionally, the morphology of the landscape favors hydro in several locations with groundwater reserves. At the same time, a shift from fossil fuel-based energy generation towards RES based is an endeavor involving many diverse challenges and thought-provoking facts:

The lack of centralized country planning. As stated by all interviewees, a central planning that considers the particularities of Greece's landscape (islands and mountains) is essential as, currently, the energy transition arrangement towards RES is driven by the liberation of the market and private interest/ initiatives. As observed in the island of Anafi, the whole transition to RES is based on proposals coming from the private sector. The municipalities, especially in the small islands that have limited technical resources, have a secondary role - supporting and approving projects involving RES, with the overwhelming majority of these projects being wind farms due to the high profit margin.

The exclusive focus on electricity generating potential of RES in the islands. Private enterprises don't invest in other uses of RES since these require longer time to pay off the investment, focusing only on solar and wind and are not going deeper into technologies such as small hydro, geothermal, biomass due to the longer cost recovery period and lower profit margin

Limited Corporate Social Responsibility to the benefits of the RES for reduction of use of fossil fuel and is not promoting communal integration and participation in a circular economy frame

Lack of proactive interaction and trust building with the communities in the small islands of RES projects and investments, with Tilos being an exception. This can be a major problem in the context of Greece where the level of trust towards the state and large companies is traditionally low.

Private interest is the driving force in initiation, installations and increase of the RES in the small islands. The small municipalities lack the technical knowhow to lead RES projects and the process of delegating this task and receiving assistance from the relevant governmental agencies requires long waiting periods.

Technical challenges such as the synchronization of the RES generated electricity with the grid, keep the cost of RES generated electricity high.

Applying the 5 criteria in the current situation that was observed in the three islands researched reveals that there is a lot to be done for an effective integration of RES in the small islands. Keeping in mind the opportunity this energy shift poses for the islands, a holistic approach should improve the effectiveness of this shift towards a circular economy approach. The energy transition from fossil-based fuel to Renewable Energy Sources in the small islands has to be regarded as something more than the installation of few wind turbines and photovoltaic panels in a part of the island. It has to be integrated in an approach that involves communities, the civil society, companies and the academic community with the principles of circularity in mind.

The Corporate Social Responsibility of the companies that invest in the RES utilization in the small islands could be an instrument for this task as a motivation for the community, going beyond the return of the 3% of the profit. The CSR could focus on investing equally into the active involvement of the communities in the RES transition through sensitization and education, but also into development of the less profitable – but more sustainable- technologies and approaches such as biomass and small hydro. Additionally, CSR can focus on the principles of "reduce -reuse – recycle" and the ReSOLVE framework that will include the primary production sector (agriculture - livestock) and tourism in an integrated approach towards circularity.

6. Epilogue

Circular economy approaches are essential for an integrated energy transition approach. Community initiatives with symbiotic, circular principles can go above solely using RES for electricity generation and ascend to a sustainable transition of the whole of the islands. Small islands in particular, being well framed and defined communities, can lead this approach, acting as model systems. In this sense, RES technologies that don't exclusively focus on the generation and selling of electricity should be considered and promoted. These technologies can be low enthalpy geothermal, small municipal plants producing biogas from biomass, heat exchange / recovery, as well as activities such as recycling, waste/ sewer mining, etc.

The use of the touristic potential can be an interactive tool for of the transition to an effective implementation scheme: RES and circular economy can act as a promotion of the island attracting eco-oriented tourism and, in a second phase, touristic activities can fund circular economy initiatives.

The academic community can cooperate with the municipalities in order to promote innovative solutions and technical expertise, as demonstrated in the case of Tilos with positive results.

Lastly, central political planning is essential in the above goals, as support through policies and policy instruments is vital for the evolution of such, nonprofit oriented, initiatives. Recent legal initiatives such as the act for energy communities is a positive evolution and can be the main focus of such initiatives.

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Τι είναι οι Ενεργειακές Κοινότητες και πως μπορούν να επωφεληθούν ιδιώτες, επιχειρήσεις, αγρότες και Δήμοι (παραδείγματα). (n.d.). Retrieved August 25, 2018, from https://energypress.gr/news/ti-einai-oi-energeiakes-koinotites-kai-pos-mporoyn-na-epofelithoyn-idiotes-epiheiriseis-agrotes

Appendix

Ethical concerns

This research involved extensive interviews with stakeholders involved in the governance and technical services of the islands researched. The interviews were conducted in a location and physical setting that provided privacy and confidentiality. The interviewees were informed in advance about the details of the interview and the management of the information that they will share:

- The personal details of the interviewer and the university that is hosting the research
- The aim of the research and the nature of questions
- The expected length of the interview
- The use of the information that they share
- The availability of the final study results and outcome
- The confidentiality of their personal details
- The fact that the interview will be recorded
- The data protection method (password protected, no moveable digital storage)
- The destruction of the identifiable data at the end of the research

After sharing the above information and the agreement of the interviewee to proceed, a consent from was signed in two copies, one for the interviewer and one for the interviewee. The consent form template can be found below.

The ethical consideration part of this research was approved by the research supervisor and received formal approval by the ethical committee of Twente University before any interview took place.

Informed consent form for individual interviews for thesis studies in MSc MEEM

Title research or acronym: *(title, names and dates can be prefilled by the researcher)*

I declare to be informed about the nature, method and purpose of the investigation. I voluntarily agree to take part in this study. I keep the right to terminate my participation in this study without giving a reason at any time.

My responses may be used solely for the purposes of this study. In its publications, they may *(please tick one of the options):*

☐ be cited with my name or function revealed
☐ be cited anonymously, thus without identifying context
☐ only used as information source

During the course of the interview I keep the right to restrict the use of (some of) my answers further than indicated above.

Name participant: ……..

Date: ………………….……………… Signature participant: …..……………………………………………………

I declare to fully adhere to the above.

Name researcher: ………………………………………………………………………………………….…………..

Date: ………………………….……… Signature researcher: ……………….……………………………………….

Έντυπο συγκατάθεσης για μεμονωμένες συνεντεύξεις, για σπουδές διατριβών στο MSc MEEM

Τίτλος Έρευνας:
(ο τίτλος, τα ονόματα και οι ημερομηνίες συμπληρώνονται από τον ερευνητή)

Δηλώνω ότι έχω ενημερωθεί για τη φύση, τη μέθοδο και το σκοπό της παρούσης έρευνας. Συμφωνώ εθελοντικά να λάβω μέρος στη μελέτη αυτή. Διατηρώ το δικαίωμα να τερματίσω τη συμμετοχή μου σε αυτή τη μελέτη χωρίς να δώσω κανένα λόγο οποτεδήποτε.
Οι απαντήσεις μου μπορούν να χρησιμοποιηθούν αποκλειστικά για τους σκοπούς αυτής της μελέτης.
Στην τελική δημοσίευση επιτρέπω *(παρακαλώ επιλέξτε μία από τις επιλογές):*
☐ να αναφέρομαι με το όνομα ή τη λειτουργία μου
☐ να αναφέρομαι ανώνυμα, έτσι ώστε να μην προσδιορίζεται η λειτουργία μου
☐ να χρησιμοποιηθώ μόνο ως πηγή πληροφοριών

Κατά τη διάρκεια της συνέντευξης διατηρώ το δικαίωμα να περιορίσω τη χρήση (ορισμένων) απαντήσεών μου πέρα από τα παραπάνω.

Ονοματεπώνυμο συμμετέχοντος____

Ημερομηνία______/ _________/ 2018 Υπογραφή_____________________________________

Δηλώνω ότι συμμορφώνομαι πλήρως στα παραπάνω
Ονοματεπώνυμο ερευνητή ____

Ημερομηνία______/ _________/ 2018 Υπογραφή_____________________________________