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Institutional & regulatory framework for island energy autonomy: the project of Tilos

Master thesis of

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ABSTRACT

The coverage of daily energy needs comes almost exclusively from conventional energy sources, i.e. oil, gasoline and coal. Despite their great contribution, they irreparably pollute the environment while they are consumed quite fast, causing their supplies to run short. Conversely, Renewable Energy Sources (RES) are replenished through natural cycles and are considered practically inexhaustible. The sun, the wind, geothermal energy, organic materials such as wood and even household and agricultural waste are sources of energy, the supply of which is never exhausted. Moreover, their utilization for energy production does not burden the environment. But in addition, they mainly have low operating costs, which are not affected by the fluctuations of the international economy and in particular the prices of conventional fuels. Renewable energy sources are the modern answer to the earth's environmental problems and that is why their use is expanding more and more. Based on the above, both the European states and the entire global community are creating legislative frameworks in which the use of RES will be promoted and enforced. Looking at renewable energy initiatives that make the Greek islands energy autonomous, the Tilos project is an important innovative initiative aimed at both the island's energy upgrade using hybrid energy supply systems and the island's energy autonomy. In the light of this specific energy initiative, the present paper examines the European and domestic legal framework for the operation of renewable energy sources, the formation and organization of the Tilos program as well as its special characteristics, while proposing the possibility of future use of this hybrid method of energy production in the continental regions.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

RES……Renewable Energy Sources
IPCC……....Intergovernmental Panel on Climate Change
GW……..Gigawatt, Unit of power
PV……..Photovoltaic
UN…….United Nations
EU……....European Union
NSRF……National Strategic Reference Framework
GHG……Greenhouse Gas
CO_2……..Carbon Dioxide
RECAI…….....Renewable Energy Country Attractiveness Index
EY…….….Ernst & Young
IEA…….…….International Energy Agency
MEE…….....Ministry of Environment and Energy
RAE……....Regulatory Authority for Energy
EC……..European Commission
PPC……...Public Power Corporation
TSO……..Transmission System Operator
$NaNiCl_2$……...Sodium-nickel chloride
DSM……..Dynamic Spectrum Management
kW……...Kilowatt, Unit of power
MWh……Megawatt hour, Unit of energy
HPS ……...Hybrid Power Station
BESS……...Battery Energy Storage System

INTRODUCTION

One of the main pillars supporting the modern model of economic development at the global level is the use of energy. Undoubtedly, modern societies consume enormous amounts of energy for the movement of people or products, for meeting the needs of households in lighting and heating as well as for the operation of industrial units. The continuous improvement of living standards is inextricably linked to the increase in energy demand. In today's era, the largest percentage of energy comes mainly from the so-called Conventional Energy Sources, i.e. thermal units that work with mineral resources, such as oil and its derivatives, solid coal, natural gas and nuclear. In short, the utilized energy results from an exothermic reaction such as the combustion of these resources, converting the produced thermal energy into another form. Essentially, these are natural resources rich in quantity in the subsoil of the planet, which, however, on the time scale of the human species are considered exhaustible, i.e. their replenishment is very slow. These effects have been found to tend to be irreversible, making the survival of future generations doubtful. Nevertheless, nature has a multitude of other intangible energy sources that have been exploited since ancient times to meet their various energy needs, such as wind and water. These forms of energy are called Renewable Energy Sources (RES), because they are linked to the daily cycle of nature and are therefore considered practically inexhaustible. In today's era, in addition to wind and water, this category includes the sun, geothermal energy and gas from the biodegradation of organic materials from household and agricultural waste. As defined by DIRECTIVE 2001/77/EC, Renewable Energy Sources (RES) are non-fossil renewable energy sources, i.e. wind, solar and geothermal energy, wave energy, tidal energy, hydraulic energy, gas, released from landfills, from biological purification facilities and biogases. The interest in the wider utilization of renewable energy sources, as well as in the development of reliable and cost-effective technologies that bind their potential, was initially presented after the two oil crises of 1973 and 1979, and was consolidated in the last decade, after the awareness of the global environmental problems. RES were very expensive at first and started as experimental applications. Today, however, they are taken into account in the official plans of developed countries for energy and, although they constitute a very small percentage of energy production, steps are being prepared that will allow their further utilization. The cost of soft energy applications has been falling continuously over the last twenty years, and especially wind and hydropower, as well as biomass, can now compete with traditional energy sources such as coal and nuclear power.

CHAPTER 1. GEOPOLITICAL, ECONOMIC AND INSTITUTIONAL FRAMEWORK OF RES IN GREECE

1.1 The geopolitical and economic framework

1.1.1 Introduction

The increasing trend concerning the needs for electricity and the inherent weakness of urban environments to develop the necessary systems to supply them with clean energy, makes it necessary to develop large infrastructures for power generation from RES. Weaning off the use of fossil fuels in all sectors, with priority in buildings and power generation, must be an immediate political priority, alongside energy efficiency and savings. As highlighted in the IPCC report (2018) which sounded the global alarm for the urgent response to climate change, pricing policies (such as guaranteed prices / operational support systems), financial tools, and the integration of cost through the pricing of carbon used energy are of critical importance for the weaning of the power generation sector from fossil fuels[1]. Another need arousing from the demand for a continuous and clearer energy supply, stands the management of system integration towards the rapid adoption of RES technologies with equal market participation.

The substantial decarbonisation of the energy sector, with the strengthening of renewable energy sources, while simultaneously reducing the use of fossil fuels, is for zero emissions for the majority of EU Member States by 2040 at the latest[2]. The goal of limiting the increase of the average global temperature of 1.5ºC presupposes the immediate start of a course of decarbonisation of the power generation sector with the gradual withdrawal of lignite and hydrocarbon burning units and the exclusion of any new investment in fossil fuels (new units and mining projects). The path towards decarbonization will certainly require many decentralized power plans from all the technologies that have a dynamic development in Greece. Although the target is set towards an increased penetration of RES at a local and regional level, as they have a de facto decentralized

[1] IPCC, 2018: Summary for Policymakers. In: Global warming of 1.5°C.

[2] Zachmann, G.; Holz, F. McWilliams, B.; Meissner, F.; Roth, A.; Sogalla, R., Kemfert, C., 2021, Decarbonisation of Energy, Publication for the committee on Industry, Research and Energy (ITRE), Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, Luxembourg.

character, nevertheless it is also the development of large installations, given the unified nature of the interconnected system and the energy needs of urban centers that do not have a corresponding power generation infrastructure so far. It is noteworthy that 2020 was the fourth year in a row that more electricity from renewable energy sources is installed globally than installed from fossil fuels capacity infrastructure and nuclear power combined. Solar PV alone added 102.4 GW in 2018, enough to meet more than 25% of France's electricity demand, up from 2017 (99GW), while for 2019 the amount for energy supplied excited 135GW[3]. When it comes to Europe, proof of this upward trend of RES constitute the data obtained from a 2022 inquiry. More specifically, 2022 was a year when wind and solar were EU's top power source for the first time ever, reaching the percentage of 22.3% of EU electricity surpassing other conventional sources, such as nuclear (21.9%) and gas (19.9%)[4].

Renewable energy systems differ from fossil fuels not only in terms of greenhouse gas emissions and pollution caused by burning coal, oil and natural gas, but also spatially. As noted in the relevant research literature, unlike lands occupied by fossil fuels, wind and solar system development areas do not suffer from pollution and other parallel uses such as agriculture and livestock. It is also important to point out that the comparison of the spatial and licensing treatment of RES against fossil fuels marks the difference of the even bolder: politically and institutionally, fossil fuels enjoy particularly favorable licensing regimes, which shows that even in climate crisis conditions, governmental policies still support the main source of greenhouse gas emissions instead of a clearer and more sustainable energy source. Nevertheless, despite the favorable licensing treatment of hydrocarbons and lignite, RES are rightly subject to a series of necessary procedures for assessing their potential environmental effects, as a scrutinising regime of licensing may be able to prevent in advance cases of environmental destruction, while also enhancing a sense of legality[5].

[3] https://www.solarpowereurope.org/insights/market-outlooks/market-outlook
[4] https://www.carbonbrief.org/wind-and-solar-were-eus-top-electricity-source-in-2022-for-first-time-ever/
[5] Mouziouras N. Renewable Energy Sources: Evolution – Forecasts, PAPEI, 2010.

1.1.2 The geopolitical framework of RES

During the last decade, the Greek energy system is in a phase of significant changes. The penetration of natural gas, the construction of trans-European networks, the promotion of renewable energy sources and energy saving and finally the liberalization of the electricity market constitute its new data. Important are the effects of these new data on the security of the country's energy supply, on reducing its dependence on imported oil, with all the consequent benefits to the national economy, on saving non-renewable energy resources, on increasing the efficiency of production processes and energy consumption, on protecting the environment and finally on improving the services provided to consumers. In recent years, the demand for electricity in our country has shown a growth rate that is much higher than the average increase in demand in Europe. The upward trends in demand are expected to continue, on the one hand because the per capita consumption of electricity in Greece is significantly lower than the European average, on the other hand because the price of the household tariff offered by PPC S.A. is the lowest in Europe.

The looming exhaustion of the energy reserves of our planet's conventional fuels (coal, natural gas, oil, fissile materials) combined with the ever-increasing demand for energy, but also the gradual worsening of environmental problems, has led modern societies to turn to technical saving and rational use of energy with the utilization of soft or Renewable Energy Forms (RES). This type of energy sources are known since ancient times and are inexhaustible (renewable) energy reserves, while their use is friendly (gentle) to the environment[6].

The following energy sources are defined as Renewable Energy Sources according to international forums: Solar energy, Wind energy, Biomass Hydroelectric Energy, Geothermal Energy of the Sea (tidal waves). The summit conferences in Rio in 1992 and in Johannesburg had as their main theme the future of our planet and sustainable development. These goals, which basically concern the continuation of life on our planet, cannot be achieved without radical changes in the structure of the global energy system. At the same time, the "Agenda 21" adopted by the

[6] International Council on Mining & Metals (2012). The Role of Minerals and Metals in a Low Carbon Economy. ICMM, InBrief. June 2012.

United Nations, calls for new policies and new programs that will aim to increase the contribution of energy systems that are environmentally safe, reliable and of low economic cost. In particular, energy systems that use renewable energy sources are mentioned for the reduction of environmental impacts, and for a more efficient use of energy, its transport, its distribution and its final use[7].

Thus, one of the main pillars of support for the modern model of economic development at the global level is the use of energy. Undoubtedly, modern societies consume enormous amounts of energy for the movement of people or products, for meeting the needs of households in lighting and heating as well as for the operation of industrial units. The continuous improvement of living standards is inextricably linked to the increase in energy demand. In today's era, the largest percentage of energy comes mainly from the so-called Conventional Energy Sources, i.e. thermal units that work with mineral resources, such as oil and its derivatives, solid coal, natural gas and nuclear. In short, the utilized energy results from an exothermic reaction such as the combustion of these resources, converting the produced thermal energy into another form[8].

Due to Greece's geopolitical position, which reflects a European edge, the country's current policy regarding RES was and continues to be determined by the European approach to the issue. Historically, the efforts to exploit RES can be seen through the summit conferences where goals were set that basically concern the continuation of life on the planet and which cannot be achieved without radical changes in the structure of the global energy system. In 1987 the UN Commission on Environment and Development concluded that it is necessary to find a new development path which guarantees not only the progress of some people living in certain parts of the world, but the progress of the people of the entire planet in perpetuity. This committee defined that sustainable or self-sustaining or sustainable development is that which satisfies the needs of the present, without reducing the ability of future generations of people to satisfy their own. During these last years, European policy-makers have had to face several challenges in the field of energy policy: the environmental and economic impacts of climate change are unavoidable, and Europe's energy

[7] Christofis I. Koronaios, National Technical University, Interdisciplinary - Interdepartmental Program, postgraduate studies, "Environment and Development", Athens March 2012.
[8] De Ridder, Marjolein (2013). The Geopolitics of Mineral Resources for Renewable Energy Technologies, The Hague Center for Strategic Studies. The Hague Centre for Strategic Studies.

security is at risk due to its high dependence on energy imports, adding to the existing uncertainties the current armed conflict between Russia and Ukraine that has recently triggered an economic energy crisis in whole Europe. In addition, the current financial and economic crisis puts economic growth and employment at risk[9].

The above mentioned clarify the fact that the implementation of RES and its technological effects that have been observed in recent years can only be compared to the industrial revolution at the end of the 19th and the beginning of the 20th century. The transition to various decisive forms of energy, from steam to coal and then to oil and nowadays to renewable energy sources, created developments not only on an economic but also on a political level. It is no coincidence that all European countries, both individually and at an overall level like the EU, have created a series of provisions to attract significant investment funds for RES and to establish new rules in political decisions (the main expression of which is the commitment to the production of 20% of the total energy produced in the EU by 2020 from RES). In the case of states with high energy demand such as the USA and China, there is a need to review their armament programs as well to invest in weapon systems less dependent on conventional fuels and to ensure the security of existing conventional energy sources. In the political field as well, the decentralization of RES in various regions gives power to local authorities and creates a peculiar democratic system with less long-term dependence on the central government. On the opposite side, the central organizations of energy production and distribution, which are mainly state bodies, do not wish to lose their monopoly position in the field and present a series of obstacles to the development of RES. At this point there is government intervention that should balance these trends[10].

From an external geopolitical point of view, the countries that currently invest in RES will have an important geopolitical role in the future. The bipolar model where on one side there is the USA and on the other the other countries in the geopolitical chessboard of energy is now beginning to decline. Some estimate that this model will be expanded with the participation of China on the other side or rather it will become a multipolar model where power will be more equally distributed

[9] Vlachou A., 2001. Environment and natural resources, Economic theory and policy, Volume I. Kritiki Publications, Athens.

[10] Cross, S.; Padfield, D.; Ant-Wuorinen, R.; King, P.; Syri, S. Benchmarking island power systems: Results, challenges, and solutions for long term sustainability. Renew. Sustain. Energy Rev. 2017.

between the various states and which will be due to the geopolitical results from the use of RES. The current technologies can exploit only a small percentage of Renewable Energy Sources. Therefore, according to Professor Marrianne Haug, a series of geopolitical questions are raised such as regarding the inequality of those who produce the energy (in a similar way as there is inequality in conventional energy), the exploitation of traditional biomass which often conflicts with health issues and poverty, the large hydroelectric projects affecting the surrounding areas or that Renewable Energy Sources put on the carpet the option of decentralized energy production and management which is not desirable in all cases[11].

Still though there are a number of issues relating to the geographical factor in terms of opportunities and constraints in various regions. The joint development of technologies for RES creates links between different countries analogous to those of conventional energy and different energy pipelines. The countries that take maximum advantage of the opportunities and reduce the various obstacles will be the ones that will have a role in the new geopolitical scene. An important factor is also the type of natural sources that are exploited for energy production: depending on the form of the natural source (sun, wind, waves), new characteristics for energy production arise. Finally, growth in renewable energy sources has brought new metals to the market, possibly produced in different countries than where the natural sources exist, such as lithium used in electric car batteries and silicon which is the main building block for photovoltaics[12].

Compared to the geopolitics of conventional energy, renewables have commonalities as well as differences. Renewable Energy Sources are more decentralized and therefore activate more local factors in contrast to centrally controlled conventional forms of energy. At the level of states, the USA and China as well as some European states such as Germany seem to have invested significantly in RES and will have a major say in the future geopolitical map. Countries such as Saudi Arabia that have played a major role in the geopolitics of conventional energy are losing ground to new states with a strong position in renewables and the critical materials that support them. And, of course, at the level of the European Union, large interconnection programs are being

[11] Chalvatzis, K.J.; Ioannidis, A. Energy supply security in the EU: Benchmarking diversity and dependence of primary energy. Appl. Energy 2017.
[12] Stainforth, T., Gore, T., & Urios Culiañez, J. "The socio-economic impacts of renewable energy in EU regions" (2021). Institute for European Environmental Policy.

created between countries in order to increase the security of energy supply and reduce dependence on conventional fuels, with all that this reasonably entails.

1.1.3 The economic impact of RES

Energy is a social good to which all people must have access, both in the energy production process and the choice of technology that will be based on the exploitation of local advantages and resources, with respect for the environment in the direction of sustainable development. The development of the social economy in clean energy production not only offers local development opportunities, but also places society itself at the forefront of the fight to get rid of fossil fuels. In 2018, the term "energy community" was introduced into the Greek reality. Energy communities are a form of urban cooperatives with the sole purpose of developing "innovation in the energy sector, tackling energy poverty and promoting energy sustainability, the production, storage, self-consumption, distribution and supply of energy, strengthening energy self-sufficiency and security in island municipalities, as well as the improvement of energy efficiency in the final use at the local and regional level"[13].

This is an important measure aimed at opening up the energy market in society, tackling energy poverty and strengthening the penetration of RES at the local level, through the cooperation of consumers, municipalities and small and medium-sized enterprises. In parallel, "renewable energy communities" are now part of EU energy law. With Article 22 of Directive 2018/2001 on the promotion of the use of energy from renewable sources, Member States must establish a favorable framework for the creation of energy communities that can produce, store and sell clean energy, ensuring the right of participation of all consumers, protecting them from unfair practices and removing administrative barriers to their development. It is estimated that by 2030, more than 50 GW of wind and 50 GW of solar owned by energy communities could be developed, covering respectively 17% and 21% of the installed capacity at EU level. The Energy Communities Act, as well as the incentives that can be provided by the inclusion in the development law of social-based

[13] Steininger, K., & Wojan, T. (2011). Economic Impact of Bioenergy Development Some evidence from Europe and the US. EuroChoices, 10(3), 31–37.

schemes for the production, storage, self-consumption and distribution of clean energy, can act as a framework for the development of a participatory and fair energy system that will offer significant benefits to society, the economy and the environment. An important incentive is also the expected financial support of the energy communities through the NSRF with 25 million euros, but more financial tools are needed, which must also be implemented through the Hellenic Development Bank[14].

Active social participation not simply at the consultation stage, but much more in the development, implementation and management of RES projects can bring multiple benefits, both to local societies and economies, and to the preservation of the natural environment. Through participative schemes and the activation of citizens, it is possible to co-decide and qualify projects that benefit the environment and local communities, to spread the profits to an important part of society and to reduce costs. They can also be utilized as a stable source of resources for the -in many cases- local government, but also contribute to dispelling any possible skepticism surrounding the benefits and value of RES. The energy communities can and must be the broad social-based centers of de-addiction of Greece from the chronic addiction to lignite and oil[15].

Nevertheless, energy resource has been the fundamental element for an economy or economic development. It is clear that economic growth mainly depends on energy consumption, which is highly responsible for greenhouse gas (GHG) emissions, particularly CO_2, as stated by Gabr and Mohamed (2020)[16]. Starting from this general environmental framework due to non-renewable sources, several national economies, after having experienced several disasters, have tried to bring about a structural change in production methods and energy use. Some countries have mainly switched to renewable sources, leaving fossil fuels to no longer be based on non-renewable energy sources. According to the EY Company's Renewable Energy Country

[14]https://ypen.gov.gr/?s=%CE%B5%CE%BD%CE%B5%CF%81%CE%B3%CE%B5%CE%B9%CE%B1%CE%BA%CE%AD%CF%82+%CE%BA%CE%BF%CE%B9%CE%BD%CF%8C%CF%84%CE%B7%CF%84%CE%B5%CF%82

[15] European Commission. Commission Staff Working Document Impact Assessment: Accompanying the document Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources.

[16] Gabr, E. M., and Mohamed, S. M. (2020). Energy Management Model to Minimize Fuel Consumption and Control Harmful Gas Emissions. Int. J. Energ Water Res. 4 (4).

Attractiveness Index (RECAI), which integrates new global trends, the countries with the most significant opportunities for investments in renewables are the United States, China, and India, three large economies that have been competing for these positions for several years now[17]. Implementing renewable energy sources (RES) is essential but still faces some challenges in some European countries.

However, it should be pointed out, in light of the concept of the economic dimension of RES, that the transition to a zero-pollution economy is particularly demanding and directly affects lignite mining areas due to the loss of jobs in lignite mines, power plants and, in general, in the lignite value chain and indirectly, due to the economic downturn caused precisely because the related activities occupy most of the local economies. The financing and investment support mechanisms belong to the positive financial elements that offer additional support towards the transition to clean forms of energy, as additional investments of 260 billion euros per year until 2030 are foreseen to achieve the climate goals. These investments are made with a view to their long-term environmental and economic sustainability and not to temporarily solve the problems of the regions. On the other hand, there is uncertainty within the energy market, as the problem of self-regulation and dysfunction of the energy market is inherent, with the increase in natural gas and electricity prices becoming more evident.

On 18/10/2021, the price of Brent, which is considered the international benchmark, moved above 85 dollars per barrel (85.53) with a percentage increase of 0.67% with its annual change being in the order of 99, 6%. European coal production has remained at high rates, especially in recent months, and the main factors explaining this phenomenon are historically high natural gas prices and poor performance of renewable energy sources[18]. The International Energy Agency (IEA) warns of a spike in oil demand in the winter. Record coal and natural gas prices and power shortages are turning energy-intensive industries to oil to stay afloat. The current increase in the price of electricity is mainly driven by global demand for natural gas, which has soared as the economic recovery has accelerated. The growing demand has not been accompanied by a

[17] RECAI (2020). Renewable Energy Country Attractiveness Index.
[18] Terzidou, E., 2021, "The Economic Dimension of the Energy Transition in Greece" Conference: Hydrocarbons in the Energy Transition, Data and Policies, Chania.

corresponding increase in supply. Natural gas volumes coming from Russia are lower than expected, which is constraining the market as the heating season approaches. Delayed infrastructure maintenance during the pandemic has also limited natural gas supplies. In addition, electricity prices increased due to seasonal weather conditions (low water levels and weak winds during summer) resulting in a decrease in renewable energy production in Europe[19].

1.2 Institutional Factors on Renewable Energy Sources

1.2.1. Ministry of Environment and Energy

The mission of the Ministry of Environment and Energy (MEE) is to maintain and improve the quality of the environment, the spatial and urban planning of the country and to promote the development in the fields of energy and mineral raw materials, in accordance with the principles of sustainable development. In order to achieve its mission, the Ministry, having a staff and coordination role, plans and promotes:

a) the management and protection of natural resources, biodiversity and the aquatic environment,
b) the elaboration and monitoring of the implementation of the national energy and climate policy,
c) ensuring energy supply and ensuring the adequacy of the country's energy needs,
d) exploration and exploitation of hydrocarbons,
e) the use of renewable energy sources, energy efficiency and the promotion of decarbonisation policies,
f) the rational, sustainable and environmentally friendly utilization of non-renewable energy resources and mineral resources,
g) the development of a national forest policy,
h) integrated spatial planning at national, regional and local level,
i) urban planning and the preservation of the architectural heritage.

[19] Clausen, L.T., & Rudolph, D. (2020). “Renewable energy for sustainable rural development: Synergies and mismatches.” Energy Policy, 138.

The Ministry of Environment and Energy, among its subdivisions, has established the Directorate of International and European Activities, which consists, among others, of the Department of European and International Affairs of Energy and Mineral Raw Materials. The following responsibilities belong to the above mentioned department (Government Gazette A' 160/17):

a) monitoring of European energy and mineral resources issues in the framework of the work of the Council of the European Union and the coordination of the formation of national positions in cooperation with the competent directorates of the Ministry and the respective co-competent bodies,
b) monitoring energy and mineral resources policies in international organizations and ensuring the fulfilment of all relevant obligations of the country, including the drafting of laws for the ratification of International Conventions and protocols, in cooperation with the relevant directorates of the ministry and their respective co-competent bodies,
c) carrying out all the necessary procedures for the payment of grants, contributions and subscriptions to international organizations and communities abroad in the context of fulfilling the international obligations of the country and the transmission of the required supporting documents to the Directorate of Financial Management for liquidation and payment, monitoring EU complaints for incomplete harmonization and implementation of EU legislation.

1.2.2. Regulatory Authority for Energy (RAE)

The establishment of a national governmental or national regulatory authority in each sub-legal order of the Member States of the European Union, with the primary responsibility for overseeing the energy sources in each Member State, was set out in Regulation 994/2010[20], a principle which Member States were obliged to establish by December 3rd 2011[21] at the latest. In Greece, the Competent Authority is the Energy Regulatory Authority (RAE) established by law 2773/1999. RAE is an independent regulatory authority, it has an independent legal personality and financial independence[22], while it is considered the guarantor of the Greek energy market.

Its main responsibility is to supervise the domestic energy market, recommending to the competent on occasion agencies of the state the necessary interventions in order to form the appropriate transitional framework for the operation of the electricity and natural gas market in order to lead it in a smooth way to more efficient forms. RAE has been assigned advisory powers as well as monitoring and control of the energy market in all sectors, namely i) the production of electricity from conventional fuels, from renewable energy sources and ii) natural gas. Furthermore, RAE assumed specific responsibilities in relation to the market of petroleum products. With Law 3851/2010, substantial changes were made in relation to the existing legislative framework governing RES as well as RAE's responsibilities. These changes concern the licensing process of RES stations. Thus, RAE assumed the responsibility of granting production licenses, with the competent ministry exercising control over the legality of its decisions.

RAE's role as a national energy regulator has been upgraded since 2011 with the strengthening of its decisive powers regarding the regulation of the electricity and natural gas markets, powers assigned to it at the behest of the Third European Energy Package, which reduces the national energy regulatory authorities into "guarantors" of the orderly functioning of the energy

[20] Iliopoulos, Issues of European Energy Law, Ant. N. Sakkoula, p. 109.
[21] article 3 par. 2.
[22] article 5 of Law 4001/2011.

markets. More specifically, in 2009 the European Union adopted the Third European Energy Package, which consists of:

- Directive 2009/72/EC, "on the common rules for the internal electricity market and on the repeal of Directive 2003/54/EC".
- Directive 2009/73/EC, "on the common rules for the internal natural gas market and the repeal of Directive 2003/55/EC".
- Regulation (EC) 713/2009, "on the establishment of a Cooperation Organization of Energy Regulatory Authorities".
- Regulation (EC) 714/2009, "regarding the terms of access to the network for cross-border exchanges of electricity and the repeal of Regulation (EC) no. 1228/2003".
- Regulation (EC) 715/2009, "regarding the conditions of access to natural gas transmission networks and for the repeal of Regulation (EC) no. 1775/2005".

According to European law, the European Regulations are directly implemented by the Member States, without the need for a process of incorporating them into national legislation. The above specific Regulations entered into force on March 21, 2011. The European Directives 2009/72/EC and 2009/73/EC were transposed into Greek legislation by Law 4001/2011, (Government Gazette A' 179/22).

Briefly, the Competencies of the RAE:

1. Evaluation and decision on applications for the granting of a production license.
2. Evaluation and decision on applications for modification, renewal, transfer of production license.
3. Issuance of certificates by the RAE Secretariat for changes to data that do not constitute a modification of a production license.
4. Opinion on the issuance of the YA (in Greek) "Regulation of Production licenses from RES and through High Efficiency Cogeneration of Electricity and Heat" (A.5, par.3, Law 3468/2006 as applicable).
5. Issuing decisions to determine details regarding technical issues and in particular issues related to the method and process of evaluating applications for the granting of a production license.

6. Issuance of decisions for the characterization of areas with saturated networks and the determination of the possibility of absorbing power from RES in them, after a recommendation from the competent managers (A.3, par.5, Law 3468/2006 as applicable).
7. Control of the System of Guarantees of Origin from RES. Cooperation with YPEKA for the biennial drafting of the report of A.21 of Law 3468/2006 as applicable, on the penetration of RES in the national balance.
8. Making a decision regarding the numerical values of the coefficients of the methodology for apportioning the Special Fee (no. 143 par.2 para.c', law 4001).
9. Opinion to the Ministry of the Environment for the increase of the sale price of electricity from an offshore wind farm up to 30% before the signing of the relevant sales contract (A.15, par. 17b of Law 3851/2010).
10. Monitoring of licensed production projects.
11. Compilation of acts establishing a violation and decisions for the revocation of production licenses or for the imposition of other administrative sanctions in accordance with current legislation.
12. Export of energy statistics.
13. Processing and Decision on Review Requests.
14. Consideration of topographical diagrams and summary technical studies in the context of issuing an installation permit.
15. Maintenance and publication of the register of licenses Provision of information (copies of files, geographical data, etc.).
16. Calculation of the carrying capacity of wind station installation areas in the context of the application of the EPHS RES (Government Gazette B΄2464/03.12.2008).
17. Creation of suitable software and capture of positions and data for each project.
18. Formulation of files and opinions on applications for the cancellation of production permits for RES projects before the Council of Ministers and responses to letters of objection from the EU regarding the licensing of RES projects.

CHAPTER 2. REGULATORY FRAMEWORK OF RENEWABLE ENERGY SOURCES

2.1. European legal Framework on Renewable Energy Sources

Renewable Energy Sources play an important role in the European Strategy for the protection of the environment. For this reason, the European Union has set certain goals that all member countries must achieve by 2020. A basic principle for the transformation of the energy field by 2020 is the achievement of a competitive, sustainable and secure energy strategy. The main objective of such a strategy is to harmonise environmental needs along with the availability of energy means. As mentioned above, Renewable Energy Sources include wind energy (both onshore and offshore), solar energy (photovoltaics), hydroelectricity, geothermal energy and biomass/biofuels. According to the European Strategy also known as "Europe 20-20-20"[23], three main objectives were set in order to achieve the aforementioned goals. These targets are as follows:

a) Reduce greenhouse gas emissions by 20%.
b) Increase the use of Renewable Energy Sources by 20%.
c) Improve energy efficiency by 20%.

In addition, all countries must increase the use of renewable energy sources in transport by 10%. By achieving the above objectives, the EU will contribute to the fight against climate change and air pollution and will also be able to become energy independent, as it will use its own resources and not foreign ones. Furthermore, the energy offered will be affordable for both consumers and businesses[24]. To achieve the goals mentioned, the Energy Strategy sets five priorities.

[23] The European Commission presented a series of proposals setting ambitious targets of greenhouse gases reduction. It announced the EU would commit itself to reducing emissions of developed countries by 30% (compared to 1990 levels) by 2020 in international negotiations. In addition, the Commission planned its commitment to reduce its domestic emissions by at least 20% by 2020.

[24]Ristori, Šefčovič, Cañete, European Commission (2010), Energy 2020 A strategy for competitive, sustainable and secure energy, 'https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union /2020-energystrategy'.

a) To make Europe energy efficient, investing in efficient buildings, products and also in transport. This will be achieved through the use of energy labeling systems, the renovation of public buildings as well as the eco-design of energy-intensive products.
b) Building a pan-European energy market by building the necessary transmission lines, gas pipelines and infrastructure.
c) Protecting consumers' rights by ensuring high safety standards, which will allow consumers to easily switch energy suppliers, monitor energy usage and resolve potential problems immediately.
d) Implementation of the Energy Technology Strategic Plan, which includes the development and deployment of low-carbon technologies such as solar energy, smart grids, and carbon capture and storage technologies.
e) Maintaining good relations with the countries' external suppliers and creating an Energy Community with the aim of integrating neighbouring countries into the internal energy market.

At this point, a brief overview of Europe's legislative initiatives is considered necessary, towards the adoption of actions that contribute to the achievement of the goal of a Green Europe, with the aim of outlining Europe's path towards an eco-friendly power resolution. The original Renewable Energy Directive, adopted under a co-decision procedure on 23 April 2009[25] stipulated that a mandatory share of the order of 20% of energy consumption in the EU must, by 2020, be covered by renewable energy sources. In addition, the same Directive established the requirement that all Member States must cover 10% of their transport fuels from RES. This directive also identified various mechanisms that Member States can implement to achieve their goals, such as support schemes, guarantees of origin, joint projects, cooperation between Member States and third countries, as well as sustainability criteria for biofuels.

On 30 November 2016, the Commission adopted a legislative package entitled "Clean energy for all Europeans"[26] as part of the wider Energy Union strategy[27]. During December 2018, the

[25] Directive 2009/28/EC, repealing Directives 2001/77/EC and 2003/30/EC
[26] COM(2016)0860
[27] COM(2015)0080

revised Renewable Energy Directive[28] came into force, promoting the use of energy from renewable sources:

- further development of renewable energy sources in the electricity sector
- integration of renewables in heating and cooling (an indicative annual increase of 1.3% for renewables in heating and cooling has been introduced)
- decarbonising and diversifying the transport sector
- create a share of renewable energy sources of 14% in the total energy consumption of the transport sector by 2030
- create a 3.5% share of advanced biofuels and biogas in 2030, with an interim target of 1% by 2025 (counted once)
- create a 7% cap on first-generation biofuels in road and rail transport while planning to phase out the use of palm oil (and other CO_2-increasing plant-based biofuels) by 2030 through a certification scheme
- strengthening EU sustainability criteria for bioenergy
- ensuring - that the EU-binding target is met in a timely and cost-effective manner

In December 2018, the revised Renewable Energy Directive[29] entered into force, as part of the Clean Energy for All Europeans package, which aims to keep the EU a world leader in the renewable energy sector and, more generally, to help the EU meet its emissions reduction commitments under the Paris Agreement. The said revised directive entered into force from December 2018 and stipulated its incorporation by the individual Member States of the Union, becoming national law in the EU countries, with effect from 1 July 2021 onwards. The directive established a new binding renewable energy target for the EU for 2030 of at least 32% of energy consumption, with a clause for a possible upward revision until 2023, and an increased target of 14% for the share of renewable fuels in transport by 2030.

Then, on 11 December 2019, the Commission adopted its communication on the European Green Deal[30]. This Green Deal sets out a detailed vision to make Europe a climate-neutral continent by 2050 by providing clean, affordable and secure energy. And in July 2021, as part of

[28] Directive (EU) 2018/2001
[29] Directive (EU) 2018/2001
[30] COM (2019)0640

the implementation of the European Green Deal package, the Commission proposed amending the Renewable Energy Directive to align its renewable energy targets with its new climate ambition. The Commission proposed to increase the binding target of renewables in the EU's energy mix to 40% by 2030 and promote the use of renewable fuels such as hydrogen in industry and transport.

Until 2020, the directive confirmed the existing national renewable energy targets for each country, taking into account the starting point and the overall renewable energy potential (with renewable energy rates of 10% in Malta to 49% in Sweden). EU countries can set out how they intend to achieve the specific targets as well as the overall roadmap for their renewable energy policy in their national renewable energy action plans. Progress towards national targets is reviewed every two years when EU countries publish national renewable energy progress reports. In the absence of revised national targets, national renewable energy targets for 2020 should be each Member State's minimum contribution for 2030. EU countries will propose their national energy target and draw up 10-year national energy plans and climate during Horizon 2030, followed by biennial progress reports. These plans will be assessed by the Commission, which could take action at EU level to ensure that they are consistent with overall EU objectives.

An important European initiative in the direction of green energy is the achievement of the European Green Agreement. On 14 July 2021, the Commission published a new package of energy legislation entitled "Adjustment to the 55% target: delivering on the EU's 2030 climate target towards climate neutrality"[31]. In the new revision of the Renewable Energy Directive[32], it is proposed to increase the binding target for the share of renewables in the EU's energy mix to 40% by 2030 and new national targets such as:

- new benchmark for renewable energy use of 49% by 2030 for buildings
- new benchmark annual increase in renewable energy use of 1.1 percentage points for industry
- a binding annual increase of 1.1 percentage points for Member States in the use of renewable energy sources for heating and cooling
- indicative annual increase of 2.1 percentage points in the use of renewable energy sources and waste heat and cooling for district heating and cooling.

[31] COM (2021) 0550
[32] COM (2021) 0557

The drive to decarbonise and diversify the transport sector includes:

- the target of a 13% reduction in the greenhouse gas emission intensity of transport fuels by 2030, covering all modes of transport
- a 2.2% share of advanced biofuels and biogas in 2030, with an interim target of 0.5% by 2025 (counted once)
- a 2.6% target for non-bio renewable fuels and a 50% share of renewables in industrial hydrogen consumption, including non-energy uses, by 2030.

In the context of the European initiatives towards a Green Europe, it is worth noting that on 19 November 2020, the Commission published a specific EU strategy for offshore renewable energy entitled "An EU strategy to harness the potential of offshore renewable energy sources for a climate-neutral future"[33], which assesses the potential contribution of offshore renewables and goes beyond the narrow definition of energy production factors. This strategy aims to increase electricity production from offshore renewable energy sources in the EU from 12 GW in 2020 to over 60 GW by 2030 and 300 GW by 2050. In addition, it envisages a legislative overhaul of the trans-European energy network to make it more applicable to cross-border offshore infrastructure.

Regarding the European policy for the use of renewable energy sources until 2030, the countries of the European Union have agreed on a framework for climate and energy which includes the objectives and policy for the period 2020-2030. The goals aim to maintain the competitive, secure and sustainable energy system that will be achieved by 2030, but also to continue until 2050. The strategy encourages private investment in new pipelines, electricity networks and the development of low-carbon technologies. The targets are based on a long-term economic analysis that will measure the economic benefits of decarbonisation until 2050. The main economic effect of decarbonisation will be the shift of costs from fuel sources to low carbon technologies[34].

[33] COM (2020) 0741

[34] Ristori, Šefčovič, Cañete, European Commission (2011), Energy Roadmap to 2050, Available online from https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2050-energy-strategy.

The main objectives of the Europe 2030 Strategy which have been set are the following:

a. Reduction of greenhouse gas emissions by 40% compared to 1990 levels.
b. Use of Renewable Energy Sources at a rate of 27%.
c. Energy saving of at least 27%.

In order to achieve the above objectives, the European Commission proposes a fundamental reform of the EU emissions trading system, together with the creation of new indicators of competitiveness and security of the energy system as well as the creation of a governance system based on national plans for a more competitive, safe and sustainable energy.

Regarding Europe's strategy for the use of renewable energy until 2050, the European Union sets as a goal until 2050, the reduction of greenhouse gas emissions by 80-95%. The 2050 Energy Roadmap looks for ways to keep pace with reducing greenhouse gas emissions, maximizing competitiveness and security. To achieve these goals, it is necessary to invest in low-carbon technologies, renewable energy sources and energy efficiency. The European Commission's Energy Roadmap sets out four pathways to achieving the 2050 targets:

a. The achievement of optimal energy efficiency.
b. Increasing the use of renewable energy sources.
c. The possibility of using nuclear energy.
d. Carbon sequestration and storage.

More specifically, in order to achieve the goals, a more efficient use of the energy produced as well as an increase in the share of renewable sources is deemed necessary, while investing in new infrastructures and replacing the existing ones with low-carbon alternative solutions. It is also proposed to create a common energy market, with the aim of consuming energy being produced where it is cheaper and shared where necessary.

2.2. Domestic legal Framework on Renewable Energy Sources

In a national level, the first legal document concerning the production of electricity from RES was established by Law 2244/1994[35]. According to the specific legal document, the production of electricity is allowed, among other sources by RES, and the amount of electricity produced could be exclusively allocated to a public power corporation (PPC), which on its part was obliged to purchase the produced amount of energy. Provisions for RES were also included in Law 2773/1999[36] which introduced an obligation for the interested parties to obtain a certified license for the production of electricity from renewable energy sources. In order to promote production, it was obligatory for the transmission system operator (TSO) to give a priority to their dispatch, whereas in the non-interconnected islands, PPC, as the administrator of the distribution network, was also obliged to absorb the electricity produced from RES. A relevant contract should be concluded with the TSO, or in the case of non-interconnected islands, with the distribution network operator (PPC).

A milestone in the pathway of national legislation concerning the establishment of RES was Law 3468/2006[37], via which the European Directive 2001/77/EC was incorporated in the Greek legal system. According to its provisions, the legal and regulatory framework for the production of electricity from RES was set as autonomous, withstraining from the general framework for electricity.

The prior set priority concerning the absorption of RES-electricity was maintained, in order to achieve national RES targets. With the aforementioned framework, the target for RES electricity contribution in a total gross electricity consumption was set at 20.1% by 2010 and 29% by 2020.

[35] National Law 2244/94 - "Regulation of power generation issues from renewable energy sources and conventional fuels and other provisions".
[36] National Law 2773/1999 - "Liberalization of the Electricity Market Regulation of energy policy issues and other provisions".
[37] National Law 3468/06 "Generation of electricity from renewable energy sources and through high-efficiency co-generation of electricity and heat and miscellaneous provisions".

Furthermore, with Law 3851/2010[38], the objective of RES participation in total energy consumption according to Directive 2009/28/EC was adopted as national target. Electricity produced from RES was rationalized, and in parallel simplified RES licensing procedure, while under Law 4001/2011[39]past regulations were basically adjusted in order to follow the new market structure.

According to Law 4414/2016[40], in compliance with the European Commission's Guidelines for State Aid, the aim for new renewable projects and their remuneration schemes was to converge and integrate better to electricity market operation at an optimum level of cost for the consumer, which would closely follow the declining cost of each relative renewable technology separately. Towards this direction, the FIT scheme was replaced with a sliding Feed-In Premium (FIP) model. New Reference Tariff prices introduced for each RES technology.

According to the explanatory report of Law 4643/2019[41], regulations are foreseen to support the production of energy from RES and the saving of energy. More specifically, Chapter V of the law includes the arrangements for RES Support. The regulations are part of the country's energy planning framework, which is primarily based on the complete de-ligniteization and shutdown of all the country's lignite units by the year 2028, while simultaneously increasing the penetration of RES production in the energy mix to 35% of the final of gross energy consumption, so that at that time at least 60% of domestic electricity generation will come from RES plants. However, in order to make the above possible with the least possible burden on electricity consumers, it is necessary to adopt legislative regulations that will have a strong development character and will strengthen the installation of new RES stations in a mature and safe environment for investments. At the same time, within the said law, it is defined that measures should be taken in order to correct omissions and mistakes of previous years, which created confusion and

[38] National Law 3851/2010 "Acceleration of the development of Renewable Energy Sources to tackle climate change and other provisions in matters of competence of the Ministry of Environment, Energy and Climate Change.".
[39] National Law 4001/2011 "For the operation of Energy Markets for Electricity and Natural Gas, for Research, Production and Hydrocarbon transmission networks and other regulations.".
[40] National Law 4414/2016 "New regime for the support of power plants from Renewable Energy Sources and Cogeneration of High Efficiency Electricity and Heat Provisions for the legal and operational separation of the supply and distribution sectors in the gas market and other provisions.".
[41] National Law 4643/2019 "Liberation of the energy market, modernization of PPC, privatisation of DEPA and support of RES, and other provisions.".

obstacles for investors to install new stations and to speed up the integration of European directives and regulations to consolidate market rules.

As has been sufficiently formulated in the context of the present study, the promotion of renewable energy sources is a vital objective for the European Union. According to the Renewable Energy Directive 2018/2001, increased use of energy from renewable sources is an important component of the package of measures needed to reduce greenhouse gas emissions and comply with the Union's commitment under the 2015 Paris Agreement on climate change and with the Union's 2030 climate and energy policy framework, including the Union's binding target of reducing emissions by at least 40% by 2030 compared to 1990. This binding target for the Union is also a binding goal for the country, as the contribution of the member states, based on their shares, in relation to their national overall goals for 2020, is inextricably linked to the above energy and environmental policy of the Union. Therefore, maximizing the penetration of renewable energy sources (RES) in electricity generation by 2030, requires the creation of the appropriate conditions for development through improved and simplified licensing procedures.

In addition, Directive 2018/2001 provides that Member States take the necessary measures to ensure that: a) administrative procedures are simplified and processed quickly at the appropriate administrative level and predictable timetables are set, b) the rules for approval, certification and authorization are objective, transparent and proportionate, do not discriminate between applicants and take full account of the specificities of individual renewable energy technologies, and c) administrative fees paid by consumers, urban planners, architects, builders and installers and suppliers of equipment and systems are transparent and cost-effective. In this context, the new provisions achieve the standardization of the elements of admissibility and the simplification of the examination process of the applications of the first licensing phase (until now for "production license"), as well as the automation of their examination in a transparent, impartial and objective manner.

In view of the above, Law 4685/2020[42] was introduced into the Greek legal order, which lays the foundations for the integration of the above Directives into Greek law, as the first stage of a series of interventions in the licensing of RES, which will be completed with the integration of Directive 2018/2001. The aim of the whole network of regulations that will be implemented in the coming years in the field of electricity generation from RES will be to increase the penetration of RES in the energy mix, in the context of the European and national policy of gradual weaning from fossil fuels and strengthening of "clean" forms energy, with at the same time obvious benefits in the field of economic development by attracting relevant investments and creating new, direct and indirect jobs.

More specifically, the proposed provisions establish a very short licensing procedure in its first stage, with a reduction to the minimum of the required supporting documents and the use of automated checks by the new information system (e.g. exclusion zones, load-bearing capacity check, distance check) and parallel reducing the financial burden for them. The new Certificate will be a safety valve for the investor, securing the position of his station, but also a lever of pressure for him to implement the project, due to the deadlines set for the next steps of the licensing process, in order to maintain the validity of the Certificate. A key pillar of simplification is, in principle, the establishment of the Electricity Producer Certificate from Renewable Energy Sources (RES) and High-Efficiency Cogeneration of Electricity and Heat (CHP) units in place of the Production License, which is established and regulated by chapter B' of this draft law. With this Certificate, the licensing process of the projects begins, without this issuance being dependent on a thorough and exhaustive evaluation of the viability of the projects and the possibility of their implementation.

Finally, with the provisions of Law 4876/2021[43] and specifically with the provision of Article 70 of the law, individual issues are regulated regarding the approval procedures for the

[42] National Law 4685/2020 “Modernization of environmental legislation, integration into the Greek legislation of the Directives 2018/844 and 2019/692 of the European Parliament and of the Council and other provisions”.
[43] National Law 4876/2021 “Arrangements for tackling the COVID-19 coronavirus pandemic and protecting public health and other emergency provisions.”.

licensing of energy production facilities through RES, aiming at a faster process of resolving the bureaucratic issues that delay the development of energy production units.

CHAPTER 3. THE TILOS PROJECT

3.1. Overview

Aiming at improving energy autonomy and energy supply security of the several existing islands in the Greek domain, an integrated energy solution, a rather interesting energy mix one would argue, has been developed based on the availability of wind and solar power, setting them a fine source for potential exploitation along with an appropriate energy storage infrastructure. This proposal stands quite promising for various Greek islands belonging to the Aegean Archipelagos area, to mention a few, and particularly the most distant and small-scale ones.

The energy self-sufficiency of a Greek island with clean energy may have seemed like a scenario science fiction a few years ago, but today in Tilos (a tiny Dodecanese island, located in the eastern Aegean) a process has started that is evolving in this direction. Tilos is changing the facts in the energy policy of the islands (interconnected and not), with the TILOS program of the same name which aims to maximize the coverage of the island's electricity demand from clean energy, through a hybrid system of production and storage of energy coming exclusively from renewable sources. The TILOS Project is a European research project that was part of the Horizon 2020 program. The project was designed, funded and built by Eunice, a member of the private sector in the consortium that now operates the Hybrid Station[44].

At the beginning of July 2017, the installation of a medium-sized photovoltaic park and a wind turbine was completed, while in January 2018 the installation of the batteries (accumulators) that will ensure the supply of energy to the island when it is cloudy or the wind is not so strong was also completed. With the operation of a hybrid functionality designed system, Tilos is expected to become the first truly "green" island in the Mediterranean. But the vanguard of the project is not limited to the borders of Europe, as for the first time in the world an intelligent, autonomous island microgrid will be created based on the presence of a hybrid station with the participation of RES units and modern battery technology.

[44] https://eunice-group.com/el/projects/tilos-project-gr/

The TILOS Project, implemented in order to introduce an integration of a RES based energy mix for the energy autonomy of the island area of Tilos, can only be seen as a great success story introducing several important innovative characteristics in the European market. More specifically, the combined operation of a wind turbine and a PV installation (hybrid power station), the application of new technology battery energy storage, the installation of DSM network/platform and the development of a large number of reliable forecasting algorithms are among the main results of the proposed strategy. More specifically, the main objective of the project is to develop and operate a prototype battery system based on $NaNiCl_2$ batteries from FIAMM, provided with an optimum, real-environment smart grid control system and coping with the challenge of supporting multiple tasks[45], including:

- Micro grid energy management
- Maximization of Renewable Energy System (RES) penetration
- Grid stability
- Export of guaranteed energy
- Ancillary services to the main grid of Kos

The battery system is designed to support both stand-alone and grid-connected operation, while proving its interoperability with the rest of micro grid components, such as demand side management aspects and distributed, residential heat storage in the form of domestic hot water. In addition, different operation strategies are going to be tested in order to define the optimum system integration.

[45] https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-energy/storage/tilos

Figure 1: *Location of Tilos island on Greece's map*.

3.2. Aims and Goals

The main purpose of TILOS research project is to develop and operate a smart, innovative electrification microgrid on the island of Tilos, in order to cover the energy needs of the residents. The smart microgrid will be based on a hybrid RES scheme (wind and PV) with advanced technology accumulators that will adopt the demanded strategies and will interact with the Nisyros-Kos electrical system through the existing electrical interconnection. Finally, it will integrate fully automated energy management and communication software[46].

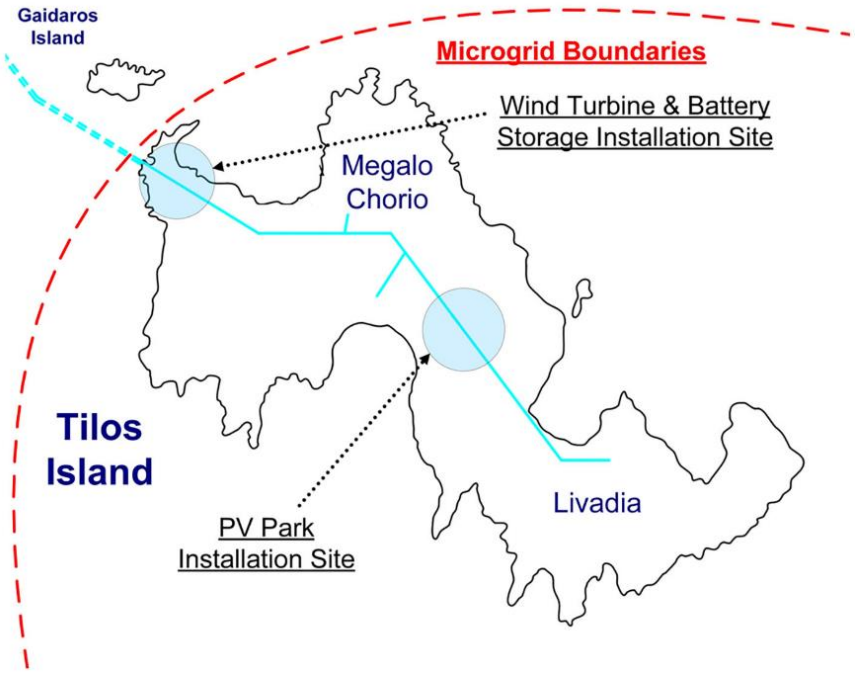

Figure 2: *Installation locations of the system's components on Tilos map.*

[46] https://www.tiloshorizon.eu/usefull-links.html

3.3. The innovation

The main objective of the TILOS project is to maximise the use of clean (renewable) energy sources in covering the electricity needs of Tilos island. In this context, a new prototype hybrid system for electricity production and storage consisting of a medium-scale wind turbine of 800kW, a small-scale photovoltaic park of 160kW and a battery storage system of 2.4MWh useful energy capacity, have been developed and operated on Tilos[47] **(Figure 3)**.

Apart from the hybrid power station, smart metres and demand side management devices have also been installed in the residential sector and other, central loads of Tilos island. Moreover, a smart energy management system coordinating the operation of the various components has also been developed to achieve the highest possible electricity autonomy and balance between intermittent RES electricity production and electricity demand, with the support also of battery storage and demand side management[48]. This project is innovative because it is the first project that signed an agreement for a hybrid station with the Network Operator of the Non-Interconnected Islands (HEDNO S.A.). This means that it offers the possibility to each subsystem, the wind turbine , the solar cell and the battery to function producing energy autonomously. This energy can be stored in the batteries and from there can be provided to the network[49]. The TILOS project focuses on island regions which constitute high priority areas. Apart from Tilos, other participating islands include Pellworm (Germany), La Graciosa (Portugal) and Corsica (France). This revolutionary project for Europe has set the foundations for the future development and replication of similar hybrid systems in island regions and remote communities facing energy-related problems.

The innovative nature of the project doesn't end at its technical characteristics, as it is the first to be realized in the Mediterranean and it will be used as a prototype for its implementation to other Greek islands. The project was also presented as the milestone project of Greece in the

[47] https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-energy/storage/tilos
[48] https://www.tiloshorizon.eu/usefull-links.html
[49] https://ecopress.gr/tilos-project-evropaiki-energiaki-protia-aname/

field of RES during the historic 2015 United Nations Climate Change Conference, COP 21, held in Paris.

(a)

(b)

(c)

Figure 3: *Photos of the Tilos HPS (a)wind turbine, installed at the northwestern part of the island, (b)PV park, installed at the central part of the island and (c)battery storage system, installed at the northwestern part of the island.*

3.4. Reporting and Results

Undoubtedly, the TILOS solution, has a bundle of features synopsized below, that allow it to be a fully effective energy system:

- The HPS of Tilos comprises the first-ever, fully licensed, MW-scale, battery-based HPS in Greece. As such, it introduced new aspects in the Greek energy agenda, when it comes to non-interconnected island electricity systems.
- The rather sophisticated battery storage system of TILOS project brought an innovation to the existing storage technologies employed, since the Greek regulation for HPSs was tailored to the operation of pumped hydro.
- The HPS of Tilos has been the first to comply with the requirements of a day-ahead dispatch operation that is based on the declaration of guaranteed energy (power) offers and which entails the need for the exploitation of forecasting means as well.
- The integrated BESS is able to offer a bundle of services including RES balancing and ancillary services to the local grid, like frequency and voltage regulation, while, under a set of conditions, it can also support black-starting of Tilos; thus standing as a novel, multiple-service storage system. To our knowledge, the microgrid of Tilos is one of the most advanced island microgrids in Europe with smart aspects and many novel technologies and components. All these novel elements, following the TILOS project demonstration stage, are gradually evolving in order to support the operation of a mature energy ecosystem, fostering in the course of time the addition of new agents and actors such as the envisaged pool of prosumers, towards the full-scale decarbonisation of the island of Tilos.

According to the results obtained, Tilos island bares an energy solution that can definitely be improved by adopting further technological features and techniques in order to improve the energy mix between the local HPS and the main grid of Kos-Kalimnos. Moreover, remarkable RES-based energy production curtailments should be minimized, introducing the opportunities of clean electromobility. In any case, the real-world operating example of Tilos island may be equally well applied in several other remote islands all over Europe with very promising results.

CHAPTER 4. DISCUSSION AND CONCLUSIONS / PROPOSAL

Renewable energy sources are now a sustainable solution, replacing conventional polluting forms of energy, in the effort to reduce the ecological footprint and the rate of depletion of natural resources. Their use is expected to increase in the coming years, making them the main source of energy for a large part of the world's population. Of course, there is a need for more and more states and agencies to become part of this change, adapting their plans and policies in such a way and to such an extent that the transition to a new energy plan finds fertile ground and thrives.

As it is known, the energy sector is an important pillar for the economic development of any country. Specifically for Greece, in recent years there have been great investment opportunities to exploit the comparative advantages of its geographical position (center of current and future energy routes, solar energy, wind energy, discoveries of natural gas fields in the eastern Mediterranean basin) in combination with the gradual liberalization of wholesale and retail electricity markets. Exploiting these opportunities is going to lead to major infrastructure investment projects, which in turn will improve the medium-long term prospects of the domestic economy.

So far, the deep and prolonged recession that shook the Greek economy in the last decade, as well as the institutional framework that poses significant limitations, has been a hindrance to this perspective. Licensing procedures for investments in the energy sector remain particularly time-consuming due to the legal framework that governs them, but also often due to the reactions of local communities who resort to justice, opposed to energy projects such as the installation of wind farms. Another disadvantage of the Greek energy sector is its high dependence on the import of oil and natural gas and therefore the unpredictable changes in their price. The country's energy dependence remains high, at a rate of more than 70%, while the corresponding percentage of the average of the 28 EU countries for 2016 was 53.6%. In addition, the country's existing energy infrastructures in several cases do not meet the requirements that would ensure the path of transition towards an energy system with low greenhouse gas emissions.

From the above, it can be concluded that despite the obstacles encountered in investments related to energy, our country has a high energy potential and can be an energy hub if we consider its geographical position. RES will play an important role in this perspective, as their use will yield multiple benefits at an environmental, economic and social level. On an environmental level, the use of renewable energy sources means lower greenhouse gas emissions, a reduction in mining, a shift from polluting agents (lignite) to natural ones (sun, wind, etc.), a reduction in the risk of resource depletion and finally achieving the goal that was talked about in first chapter, for a "clean" and affordable energy for all.

On an economic level, as Greece and due to its geographical position is an energy hub, it is extremely important to encourage and allocate resources and funds to RES investments, making our country a strong energy power and greatly reducing its dependence on imported forms of energy. The higher the penetration of RES in Greece's energy mix is, the greater the contribution to the diversification of energy supply and the country's energy autonomy may be, offering an effective solution in cases of unpredictable external fluctuations in energy prices like the resulting ones from Russia-Ukraine war. Further, as far as Greece's islands is concerned, the increasing coverage of energy demand from RES can contribute to the decrease of imported energy, thus to the reduction of the common charges imposed on all electricity consumers nationwide that subsidize the more expensive fuel imports for the islands.

On a social level, the greater penetration of RES in the energy market is expected to reduce the price of electricity by increasing consumer surplus and making electricity more accessible to more citizens. In this way, and of course in parallel with other targeted policies, it is possible to deal with the phenomenon of energy poverty as effectively as possible. In summary, for all this to happen, our country should implement the long-term energy planning that was established, in order to strengthen its position in the global energy market and achieve the global and European environmental goals that have been set.

Summarising, a set of measures taken should include:

• to achieve even greater synergies and cross-border connections,

• to develop and further strengthen the electrical grids in order to allow greater penetration of RES units for power generation,

• to increase the transmission and storage capacity of the network in terms of RES,

• to improve the energy efficiency of the building stock,

• to promote RES in all sectors of final energy consumption,

• to further liberalize the electricity market.

In the last decade, our country was tested by the strong blows of the economic crisis, and in fact the strength of our economy is being tested once again under the weight of the impending threat of the pandemic as well as the war between Russia and Ukraine. Nevertheless and despite the economic crisis that paralyzed a very large part of the economic activity, our country proceeded with important reforms in the energy sector, established the national energy plan and generally set goals and followed guidelines in order to respond to the urgent environmental requirements. The further penetration of RES into the economic life of the country could be the springboard for a new reality, where the exploitation of the planet's renewable resources would not only encourage efforts to preserve our natural environment, but would also act as a driver of economic development and consolidating our position in the European and global energy scene.

The promotion of energy from renewable sources is a vital part of the European Union's energy policy and contributes significantly to the implementation of the Energy Union Strategy Framework. The new post-2020 regulatory framework proposed by the Commission as part of the Clean Energy for All Europeans package in November 2016 builds on the experience gained under the existing Renewable Energy Directive. It aims to further 'Europeanise' policy on renewable energy and maximize its use in the building sector, transport and industry. The sectors of electricity, transport and heating and cooling are at the center of a series of specific measures, while it is proposed that the national targets for 2020 be used as a reference basis for the further progress of the Member States after 2020.

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