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Monograph

An Empirical Effective Method for Energy Transition in a Regional Energy Semiautonomous Spatial System: The Case of REMTH

E. D. Stathakis

Department of Physics, International Hellenic University, St. Lucas, 65404, Kavala, Greece

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Abstract

The recent rise in prices of energy, electricity, NG, liquid fuels, combined with geopolitical developments highlight the biggest problem called the “energy transition to the decarbonization of the energy mix”. Geopolitical developments and tensions are open to many interpretations. But everyone seems to agree on the energy transition, which is an insurmountable need to stem the climate crisis. It is a condition for our existence on the planet and our country and EU rightly aspire to be the first continent with energy neutrality by 2050. But such a vision will require huge investments of 100 billion till 2050, or 3bil/ year (McKinsey study 2021), and the right strategies and time to be implemented. Like any major structural change, the energy transition has risks such as, the transition to benefit few and create a new energy poverty regime, to make Greece a mere consumer of imported know-how and RES technology. The good development is, firstly transition to help country and its regions to produce high added value technologies in-home and secondly the speed of transition to be the best so that it didn’t destroy the existing energy infrastructure long before new ones are ready to replace them. The transition requires a plan to be effective but also to benefit everyone. In this context, the National Energy and Climate Plan (NPEC) which was first formulated in 2018, needs to be reformed and to adopt the new objectives of the European Green Agreement and new strategies and actions in this direction. 1. Energy goals to be tackled in parallel with climate and social goals-easy access to energy for all, elimination of energy poverty 2. Decisively support the potential for strengthening the Energy Democracy through self-production and self-consumption of individuals and communities, while at the same time, the public sector and large companies will have to invest in the new smart technologies for offshore RES, new biofuels, green H2 3. Develop a scientifically proven framework for the promotion of RES and other energy infrastructure in terms of location, environmental impact and biodiversity protection, the faster development of RES, the promotion of smart electricity storage systems and new smart transport infrastructure 5. To pay balanced attention to investments in production of green energy and to savings with generous support in the upgrade of buildings quality, vehicles and in production process 6. The withdrawal of lignite plants should be done in relation to the development of new power production systems so that energy costs to remain at reasonable levels 7. The energy transition requires the involvement and support of the domestic potential universities, research centers, companies and organizations, local authorities so that the energy transition to upgrade the know-how and consequently the added value produced in our country. These are the issues analyzed in this monograph, mainly at the level of the EMTH region and less at the country level.

Keywords: Energy, Case Study, Transition, Spatial System

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1. Introduction

1.1 Energy Mix

Climate deteriorates and needs global interventions to stop this bad development for the future of our planet. An international approach implies essential coordinated actions to tackling such as challenges of climate change. International actions for stopping climate change will must encourage and respond to the principal role that some countries may take in various ways. They must be based on the principles of efficiency, effectiveness and fairness which have already formed the basis of the existing multilateral framework. Thus, an effective response to climate change will depend on the creation of conditions for international collective actions. International co-operations, globalization of coal taxes and the use of renewable energy sources (RES) can accelerate the transition in the majority of countries, or regions. Yet, greater international cooperation to accelerate and disseminate technological innovation to less developed countries will reduce the global transition costs. Technology transfer from the private sector to less developed countries can be accelerated through national or international partnership schemes. Researches regarding the cost of not transition show that the direct opportunity cost in 8 countries responsible for about 70% of GHG emissions is about € 50 billion a year, although marginal costs are expected to increase over time (Stern’s reports 2020).

Because someone cannot predict the consequences of climate change caused by humankind with certainty 100% through mathematical models, there must be at least one well-documented strategy and a combination of methods able to support very effectively the energy transition to a zero-emission of Green House Gases (GHG) economies on spatial basis, continents, countries, or regions. Addressing these global risks related to climate means, in one hand one takes effective initiatives to reduce GHG emissions, and in other hand societies must perceive such costs as a long-term investment, as costs to be borne today in order to avoid future risks much more serious and irreversible. If these investments are made with smart planning and evaluation process, the

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*E-mail address: estathakis@physics.ihu.gr

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needed costs will be manageable and there will be emerged a wide range of opportunities for sustainable economic growth. It is noted that, due to different cost and energy market structures, such markets introducing RES technologies after 2005 as the best transition tools, have developed very differently. The energy markets(-Denmark) to which wind power plants (W/P) dominated, reached to goals put in advance faster than those energy markets based on Photovoltaic technologies (P/V). In second case lies Greece and Region of East Macedonia-Thrace (REMTH) for 3 reasons, first Greece has more shiny hours from other EU countries, second the unique initial investment cost as €/MWh (CAPEX) is lower than in W/P and third the land finding and P/V installation is very easier than those of W/P. To be achieved the transition goals, meaning to an economy based almost on zero-carbon production systems, it is needed to be addressed and implemented many actions and projects. Yet, are necessary, consensus by local societies, standardized rules and adhoc institutions so that to be eased and overcome some markets failures and decision makers to focus on transition taking in account the long-term benefits. All the previous are the essence and philosophy adopted by this monograph consisting of the roadmap of the energy transition to a zero GHG economy in the REMTH. Yet this essay, in order to give a clear picture about the strategy for transition, uses adhoc technoeconomic tools such as, Desk Research based on official databanks, Field Research based on Delphi method, Statistical Analysis of data resulted by field research, Social Cost Benefit Analysis-SCBA for the mega-projects and a Simple Form of Benchmarking Analysis-SFBA. Although, we met great difficulties due to lack of all needed data in a well-structured timeseries form in regional level, the existence of complete timeseries in national basis help us to bring-off this work. It was needed to make some adaptations and compilations in regional data, achieving to create a complete well-structured data timeseries of 20 years period. After that, we propose the needed projects/actions based on global experience adapted to Greek reality, we evaluate all proposals, starting from RES best percent and technologies-which match better to REMTH's environment- and continue with energy saving systems, smart micro, and macro grids, and finally we present the necessary steps and tools, giving a step by step roadmap. The innovation of this work lies to the fact that it gives a complete and detailed method that is able to optimize the planned transition roadmap that minimize the time and costs and maximize the total benefits. In other words, it suggests a cost-effective transition roadmap, considering all the parameters of a feasible transition and not one, or some of them. Even, we have taken into account the extreme conditions should take place in region's Electric System-ES owing, either to extreme weather conditions, or to unpredictable reduction of power generation unable to respond to peak demand due to high penetration of RES with stochastic production. It is noted that, projections for energy demand have been done for 3 milestone, 2030, 2040, 2050, since and Greek official authorities in their studies made energy demand predictions in national/ regional level for the same milestones, and these help us to make our work. It would omit if we didn't refer to some adhoc key energy developments influencing much the transition process such as, more extreme weather, high penetration of RES and new flexible energy storage systems, great use of electric vehicles-EV, new ways of energy management via smart grids and meters, new ways of GHG emissions reduction, and new peak demand forecasting methods based on Machine Learning. Conclusively, central contents of this study are:

- Analysis of the current situation of Greek/REMTHs E.S and the future market development of P/V -W/P towards the energy transition along with the views of regional societies regarding the degree of RES acceptance.
- Assessment and evaluation of the different technologies, performance and financial parameters based on SCBA method of the individual P/V, W/P technologies.
- Indicative but well-documented proposals for a fast and cost-effective energy transition roadmap in step by step form. The figure below gives a very clear picture of the negative impacts on whole ecosystem of today energy mix.

Fig. 1. The negative impacts on whole ecosystem of today energy mix-source: /www.rivm.nl/en/life-cycle-assessment-lca/recipe

Considering the high correlation among climate and energy sector as a "sine qua non" fact we approach the transition as a complex issue. It means our approach is a multi-method in order to be able to deal with all technoeconomic factors evolved to energy cycle, power production mix, supplying, transmission, distribution. Such tools will be **a.** the max/minimization of energy production function f=(X), (Xi=are all independent variables such as, power technologies, capacity factors, marginal and average costs, degree of pollution expressed in CO2/GHG emissions/KWh) **b.** Regression analysis **c.** descriptive and inferential statistic and **d.** Social Cost Benefit Analysis (SCBA)

1.2. Multi-level Perspectives (MLP) of transition and assumptions used in our technoeconomic analysis for a cost-effective energy transition

Since the climate change is a very complex and multi-factorial issue, it needs analogue approaches. A useful tool for cope with this complex matter is Multi-level Perspectives- MLP analysis that analyze the dynamics of transition that combines technical, social, historical factors. It means it is needed to use a framework based on three-level interactions, socioeconomic, technical, innovative, and environmental. In order to create the future best paths of transition to energy systems, we must first to sort out key elements of the current situation, as well as to identify key processes that affect the dynamics of change and stability. The figure below presents the degree of complexity and multifactorial of transition.

The table below presents in brief financial and technoeconomic assumptions used in our model for optimization energy transition.

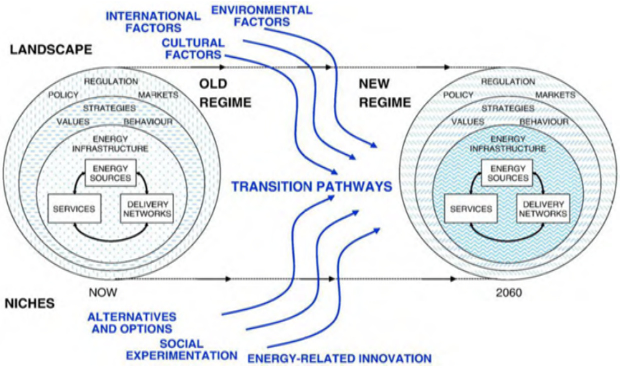


Fig. 2. Schematic representation of MLP analysis of transition (Source: Foxon, Hammond, Pearson (2010) Schematic representation of MLP analysis of transition (Source: Foxon, Hammond, Pearson (2010).

Table 1. Technoeconomic assumptions used in our modeling analysis.

Parameters or variables	**Unit for measuring**	**Reference value**
Time horizon	**Years**	**25,00**
Regulated WAAC-basic tariff renumeration	%	6,50
Extra plus WAAC	%	1,95
CO2 average prices €/kgr	€/Kgr	50,00
Real social discount rate-RSDR	%	2,95
Real financial discount rate-RFDR	%	5,00
NG average price	€/CM	50,00
GHG emission figurative cost for local societies	€/Kgr	35,00
Average electricity tariff	€/MWh	15,00
Depreciation period	Years	25,00
Average investment cost per MW and type of RES	€/MW	Per type
Energy consumption increase rate- compound annual growth rate in Italy over the period 2001 – 2019	%	1,40

Source : 2000-2020 reports of RAE, DEI, HELSTAT)

1.3. The dramatic climate change as a key-reason for this monograph

In recent years, climate change has been the focus of many experts who try to explain the potential effects of climate on the economies and environment of certain more vulnerable countries/ regions, beyond the global impacts in general. Based on a recent analysis modeling of, the Swiss RES Institute, the IPPC and the IEA regarding the estimated effects of climate change, we give a synoptic presentation of forecasting mega- impacts till 2050 using numerous of data after their necessary adaptations and compilations. The 3 most negative mega-trends about the climate deteriorate conditions lead us to deal with this matter.

1. There is no doubt that the quantities of GHG emissions have increased compared to the pre-Industrial Revolution era and for that human are to blame.
2. There is no doubt that global warming is occurring, and sea levels are rising. Since 1850 the average temperature of the earth has risen by 0.75° C, or an average terms 0.013° C every decade and sea level rose by 0,25 meters.
3. These mega-trends mean that the cost for the return of climate of our planet before to 1970 conditions will cost more than the GDP produced annually by all countries.

Fortunately, due to above bad developments, a summary of scientific knowledge years is made in reports of the Intergovernmental Panel on Climate Change (IPCC) every 5-6 keeping in alert experts, societies, and citizens.

1.4. Explanations regarding the structure of this monograph

For many decades societies have been trying to understand why climate change exists and why they are unable to tackle the problems posed by climate change effectively. The obvious results are, environmental degradation due to overexploitation and depletion of resources, abrupt extreme changes in climate, and huge damages caused by more frequent extreme weather events. The main tools towards of reducing climate change are, the reduction of fossil fuels use, the best % penetration of RES, the significant reduction of GHG emissions by 2050, as well as the protection of the final consumers from high energy prices and monopolies. At the same time, the use of Carbon Collection and Storage(CCS) technologies are the most essential choices in planning the transition to sustainable growth conditions in planet earth. In this direction, Greece, therefore REMTH, had to choose from three basic scenarios of energy transition to zero GHG emission economy [1], [35], [54], [100].

1. **The Existing Policy Scenario-EPS**: suggests a conservative implementation of energy and environment policies providing, on the one hand a moderate level of CO2 emission reduction by 2050 (40% compared to 2005), on the other hand, moderate penetration of RES and energy savings-50%.
2. **The scenario of max RES penetration-MAXRES**: suggests the max penetration of RES, 9-95% in power generation, a reducing of GHG emissions by 60-70% and energy savings in buildings and transport by 65% and 75% respectively.
3. **The scenario of min environmental cost-MINEC**: suggests a max penetration of RES 85-90% in power generation, a reducing of GHG emissions by 55% - 65% and energy savings in buildings and transport by 55% and 75% respectively.

In this work and for our modeling, we adopt the **scenario 3** for two reasons, the environmental targets of reduced GHG emissions by 55-65% are achievable and the cost of transition is lower for the country and REMTH by 12,2% comparing to other 2 scenarios.Based on the data in regional and national level and adapting and compiling them in well-structured timeseries, we procced to analyze them statistically and economically by descriptive statistics and SCBA tools. So that, we approached techno-economically the why, how, when the energy transition of REMTH to a sustainable economy with almost zero GHG emissions should be managed. It is noted that REMTH, as a Greek region, has mostly the same energy techno-economic characteristics with the country by 90%.

Our work is divided in two parts, part one is referred to present situation of energy sector and climate and second one, to future situation after transition. The first part is divided in three sub-parts. The first introductory sub-part deals with the global and E.U energy systems, the challenges they face and their interaction with climate change.

In second sub-part a reference is made to the today Greek and REMTH's energy systems from all their aspects. In this sub-part we analyze the effectiveness and efficiency of Greek and REMTH's energy systems. Issues like self-sufficiency of ES and indicators measuring their es energy efficiency are referred to, since they influence the transition cost-effectiveness. Also, we approach the innovations in energy systems as tools towards a regional sustainable economy. The second sub-part is divided in 5 parts. In first, we refer to methodology and data used to give some necessary explanations. Special reference is made to the energy forecasting supply/demand models, giving an outline about future energy topics necessary for planning on national/regional level for 2020-2050. Also factors like, influencing energy demand in national/regional level, encouraging/discouraging the energy demand in national/regional economy and funding sources for finance the cost-effective energy transition projects and actions have been analyzed in deep. In second we refer to a general roadmap that has to rule and drive a successful energy transition in Greece/ REMTH. Growth goals have to be clear and compatible to optimal way for energy transition, meaning the best RES share in energy mix, the min GHG emissions and the best ratio of costs and benefits yielded. In third we define the REMTH's transition roadmap step by step in which included large-scale projects for the power production with the highest, but techno-economically optimal RES share in power mix. Also, we propose some interventions that have to be done to national energy market helping the competitiveness and effectiveness of REMTH's regional market. Also, this part deals with the EU planned projects, the GHG emissions, the successful transition, the green economy, the emissions trade system (ETS), the Cycling Economy and the huge new issue of Energy Storage Systems. In forth, we analyze some socioeconomic aspects of energy transition in combination with a synoptic Social Cost Benefit Analysis (SCBA) method. It is studied the contribution of transition to regional development, employment, local technological added value, environmental or not environmental external economic costs[100], [98], [87], [82]. In the fifth it is become a synopsis of all previous, making some critics, comments and adhoc indicative proposals for more cost-effective energy transition in REMTH.

1.5. Climate global diplomacy as a factor promoting energy transition

Energy diplomacy goes beyond the traditional narrow definition of diplomacy, deals with the systematic monitoring of international energy developments. It emphasizes on, the development of NG, oil and electricity networks, the management of energy relations with other countries, the formation of international cooperation schemes and the cultivation of contacts with players in the international energy market. So energy diplomacy ensures security of energy supply. Yet, energy diplomacy aims to exercise influence on other countries through negotiations, smart managing of international relations and promoting energy cooperation in changing best practices and power for mutual benefits. The practice of energy diplomacy is limited mostly to state players and aims at the security of energy supply. But great role in energy diplomacy should play and private players Public and private players could be grouped into the following categories: (a) Government Agencies (b) International Organizations (c) Energy Companies and (d) Interest Groups All these can support the process of energy transition. Energy diplomacy can play great role exempt to ensure security of energy supply, to improve competitiveness and sustainability of national energy systems. Greece is called upon to manage its relations both, with its all European partners and with other international NG producers/ players such as the USA and Russia in a balanced way, keeping in mind the conflicting interests and the thin lines of international politics. The EU must play its adhoc role, through economic and political means. It can promote better energy transition and greater security and stability on its abroad- borders. EU must invest € billions in energy infrastructure that will help its energy supply security-own production and long-term contracts with NG suppliers. Yet, EU have to focus on international law and smart multilevel diplomacy in managing climate change by: **a.** managing international agreements on climate change, Rio - Kyoto – Paris, **b**. claiming to be respected treatments concerning the climate change. **c.** negotiating with other international environmental entities. It is deserved to refer that the last environmental agreements address cross-border pollution problems such as, air pollution, protection of closed and open seas, protection of endangered species, protection of wetlands, assistance in the event of a nuclear accident, cross-border transport of hazardous waste, etc. EU moves slowly, but to right direction to ensure energy adequacy and the scenario surrounding the Russia-Ukraine crisis, are expected to have a detrimental effect on the price front. For Greece, the evolution of its energy dependence was very unfavorable, from 69,1% in 2000 increased to 81,4% in 31-12-2021.

After all, the energy issue is now central to foreign policy and diplomacy. The great dependence of EU from Russian NG set-off the huge energy problem about the very high prices it pays. [20], [54].

1.6. Conclusions of introductory part

The energy sector, whose direct contribution to the EU and Greek/REMTH's economies is estimated at 4% to 5,6% of GDP (EU 28-2019), is at the heart of policies to tackle climate change and achieve sustainable growth. Greece, like other EU member states, must become climate neutral by 2050 through certain steps and projects. EU in the energy transition issue put in force rolling plans-directives and strategies-that are obliged for members but operate with a flexible way, helping countries to make the right adaptations in order to achieve the best transition. European Governments seemed to want slower transitions, while societies pushed for faster transition. Europeans decided to go in a decarbonized economy faster without a realistic plan, without prior investments, many energy suppliers, without ensuring population needs with cheap energy and now pays the forfeit of Russian energy monopsony by 46,5% in average terms. Further, the Ukrainian crisis/conflict threatens to drive energy costs even higher, forcing EU nations to de-grapple with their deep dependence on Russian fuels. [21], [22], [24], [29]. The figure below shows very clear how the today spatial electric systems will be redesigned in order to be more decarbonized, friendly to climate, protecting people's health and much more cost-effective to all their operations.

2. Part One: Present Situation Of Greece/Remth's Energy Systems (Es)

2.1. Region of East Macedonia Thrace-REMTH

2.1.1. An outline of energy economy of REMTH-some comparison with Greece

Initially it is stressed that the Greek energy sector is the more global competitive after the maritime one, contributing the 4,8% to GDP and 5,3% to employment. In REMTH the corresponding data are 8,4% and 8,2%.

Fig. 3. The EU countries' energy dependence: source: cenergyholdings.com.

In order to understand in deep the importance of energy sector in national and regional economy we give some key-data in the table below.

RES producers enjoy today (2021) good prices in annual average terms, from W/T 84,7 €/MWh and P/V 72,1€/MWh.

REMTH is located on the N.E of the country, occupying a bordering position consisting of the external Northeast borders of the EU. So, Region's position is an "eccentric" position in terms of the spatial traditional "axes of development" of the country. In the last 15 years, however, REMTH has been transformed from an "outlying region" into a "gateway to the country and the EU". Key factors contributing to this transformation were, the completion of the Egnatia Motorway crossing the northern Greece from east/REMTH to west-Adriatic sea. Its climate is mild, with enough rains, little snow, enough exploitable winds and shiny. The demographic pyramid and the structural indicators of aged population show a socioeconomic deterioration trend. Its GDP/capita throughout the 20 years, 2000-2019, has not exceed the 70% of E.U in average terms, despite the small but temporary improvement, from 63% in 2000, to 70% in 2009 and again falling to 64% in 2019(62). It is due to the accession in EU of 11 new members from former East Europe having obsolete production systems but very lower labor cost and well-skilled workforce in heavy industry. Its performance in innovation and patents bearing is not satisfactory, it belongs to the category of regions with high productive capacities but low innovation performance, ranking in 7th place among the 13 regions of the country and in 214th among the 273 EU regions (62). Regarding the sectoral structure of its GDP in 2018 comparing to 2000, there is a significant decline in the primary sector to 8,8% from 12,6%, a small increase in the tertiary to 74,4% from 69,9% and a decline in the secondary sector to 16,5% from 17,8 due to the gradual tertiarization of its economy. Agriculture sector continues to contribute to GDP triple per cent, regarding the average 3,1% of country [62].

Table 2. Features of energy sector in Greece and REMTH (2019)

Features of energy sector	Greece	REMTH	Share %
Population	10.568.000	611.350	5,8
GDP in mill €	179.600.000.000	7.140.000.000	4,0
GDP/capita in current value	17.890	11.920	66,6
GDP of energy sector	8.640.000.000	599.800.000	6,9
Revenue of electricity sector	6.650.000.000	462.000.000	6,9
Competitive revenue of electricity -concerns RES	4.050.000.000	302.000.000	7,5
Electricity end-users or clients	7.460.000	363.000	4,9
Electricity consumption KWh/user	4.233	3.860	91,2
Taxes paid by end-users	3.756.000.000	157.752.000	4,2
Shiny hours as 20 years (2000-2019) average	2345	2005	85,5
Windy hours as 20 years (2000-2019) average	3.562	3.654	103,0
Windy speed as 20 years (2000-2019) average	7,2	7,8	108,3
CO2 produced in Kg/year/person	572	543	95,0
Pollutants owing to households in % of total	25	26	104,0
Pollutants owing to various factors in % of total	45	48	106,7
Pollutants owing to transportation in % of total	30,0	26,0	86,7
Houses with P/V on roofs %	2,5	1,7	68,0
Houses with solar heating systems on roofs %	33,0	27,0	81,8
Houses with central heating systems %	58,0	43,0	74,1
Houses using woods for heating %	27,8	37,6	135,3

Source: HELLASTAT 2020 report -Public Power Corporation 2020

Sectors with a significant share to Gross Value Added are, public administration, almost 6%, manufacturing 19%, and construction 4,1%. The most dynamic sectors with strong export orientation are the agri-foods, pharmaceuticals, and marbles-mining/manufacturing. An important negative fact for region is the great deindustrialization after 1998, its industrial basis was destroyed due to many reasons, mainly due to globalization and hard competition coming from former East European countries [79]. The industry with ever-increasing prospects was and remains the energy sector. Its environment, terrestrial and wetland ecosystems, largely retain their naturalness [73]. Anthropogenic activities are the main factors in the pollution of the natural environment, while the rivers Evros and Nestos are particularly polluted by the wastewater that ends up in them from Bulgaria, without prior treatment. In general, there is a strong need for a comprehensive plan for effective environmental management and protection of its natural resources. Also, it has good geothermal fields-it is estimated that about 200 MW of power can be produced by geothermal with 30o-90o C enthalpy. This power can be used for: heating/cooling buildings, swimming pools, greenhouses, for drying agricultural products, for soil heating, for seawater desalination, for bath therapy and for liquid wastewater management. All that helped us to understand the potentialities of REMTH for energy sector, the today structure and advantages/disadvantages of its electric system (ES,) RES best spatial carrying capacity and energy transition difficulties [70], [71].

2.1.2. Energy transition theories and their implementation in REMTH

Initially we stress that REMTH was selected for three key reasons, firstly it has significant thermal and RES power units, secondly its geographical position helps to consider its ES as not interconnected to rest national one, and thirdly, there is an important additional exploitable renewable sources, on/offshore ones. Taking into account the conceptual and empirical insights from energy transition theories, we dealt with multiple facets of governance of energy transition issues concerning the certain region.

1. **Regional network governance:** it concerns, goal-setting, planning and power policy making, institutional rules, formal mandates to act properly , process and network project management, presence of a regional network reorganization, legitimacy, commitment and compliance to common goals, and leadership and control.
2. **Characteristics of the effective regional governance:** it concerns, adoption of transition goals, clear motivation for all decision makers, easy access to and ownership of resources, competences, knowledge, capacities, clear ownership of critical infrastructure dependencies, such as need of inter-municipal collaboration, organizational culture, consensus, adaptive management, and elimination of hard bureaucracy.
3. **Structural characteristics of the regional administrative network**: size of network, degree of its complexity, effectiveness of decision-makers, interregional cohesion of goals, presence of energy clusters, sub-networks and coalitions and their degree of linking to other networks.
4. **Regional networks composition and performance**: Degree of power actors membership and heterogeneity/homogeneity, interaction of regional subsystems, multi-level/sector scope, interaction with incumbents and culture of interaction.
5. **External players:** national economic circumstances, presence of natural resources and competitive enterprises, formal status of region capable to embed governance structures, regional politics and policy priorities presence of energy units and infrastructures.

2.2.The key-energy transition goals for Greece/REMTH

2.2.1 The 10+1 ambitious transition goals for Greece in brief up to 2050

- The lignite as fossil fuel remains till 2025, according to NPEC report 2020.
- Adoption and acceptance the roadmap leading to the zero carbon footprint.
- Adoption and adaptation of new IAET (DEDDHE) energy adequacy study 2020.
- Adoption more adhoc measures to improve energy efficiency and its cost-effectiveness.
- Adoption the best share % of RES penetration for power generation, coming by 90% from inshore and offshore P/V and W/T systems.
- Adoption the process to transform biogas to biomethane and inject it into the existed NG pipelines network as mix gas.
- Intensive projects for green hydrogen production through electrolysis and electricity produced by RES. The hydrogen will be used in a mixture with NG will be used in energy intensive industry and transport.
- Extension of electrification of every type vehicles.
- Application of CO2 capture technologies and use it for the production of synthetic fuels.

2.2.2 The 10+1 ambitious transition goals for REMTH in brief up to 2050

- Adoption the concept of holistic sustainability with predetermined development goals.
- Development of smart strategies for sustainable and smart mobility of resources through the promotion of RES and the development of Energy Storage Technologies (EST).
- Achievement of climate neutrality gradually by 2050, meaning a dynamic transformation of economy and reduction of GHG emissions through adhoc activities and related policies.
- Almost zero pollution from chemicals, and toxic substances through recycling systems.
- Designing of smart systems for the treatment of all types of waste.
- Supplying of 90-95% clean, safe, and affordable energy in every human activity.
- Drawing Master and Action plans up for the circular economy with a modern initiative for the management of sustainable products and packaging that will emphasize applications in areas of resource intensity, textiles, construction, plastics, and toxic waste. -Promotion the strategy “From Farmland to Fork” of organic and certified agri-food products, meaning the direct connection of production with consumption.
- Promotion of biodiversity, which is also a pillar of environmental protection and sustainable development for EU policies for its 273 regions.
- Upgrading and improving the overall energy system of REMTH in order to attract significant FDIs to support the new sustainable growth and effective ES.
- Improvement of overall environmental system in order to attract people who will want to live in REMTH, fact leading to an increasing its population till 2050 from 612.000 to 900.000 inhabitants [4], [7], [10], [11].

2.2.3 The 5+1 key-trends of global energy sector towards 2050 in brief

- Electricity global demand increase annually by 1,8% due to electrification of transport means and new former poor areas in Africa and Asia.
- In the energy mix, RESs grow very fast and fossil fuels tending to zero, estimating only 5% till 2050. Several tipping points lie ahead in transition, tracking signposts which will help business leaders to assess the direction and pace of change in the years to come.
- Energy demand will rebound quickly in post-COVID-19 era, causing great increase of NG/ KWh prices. This

energy turmoil seems to last at least 5 years till will reach a new balance point between demand/supply energy.

- Reduction of peaks in demand for fossil fuels will occur later than initially projected, oil peaks in 2029 and NG in 2037. Yet, NG will continue to play a role in the ES's by 2050 fueling alert reserve units, driven by growth in areas such as chemicals and aviation. In EU these developments will take place five years earlier than USA.
- Despite rapid shifts in the previous perspectives, GHG emissions will decline in BRICS countries by only 50% till 2050, implying a 3.5°C pathway. In EU these will happen 10 years earlier.
- Moving to the 1.5°C pathway, requires stronger ambitions and accelerated implementation of energy mega-projects at a global scale [16], {17], 18], [89], [90].

2.4 Mid/long-term Just Transition Plan (JTP)-Readiness of Greece/REMTH.

To the table below is given the predictions for readiness of Greece/REMTH to transit in a new era with the min GHG emissions. We present energy technoeconomic characteristics for them for first time, giving a real picture concerning their present and future structure.

Table 3. Predictions for Greece/REMTH about to how will have to be basic technoeconomic characteristics of their ES.

Midterm transition goals of Greece- quantified goals till 2030	Greece	REMTH
Total GHG emissions (MtCO2)	60,6	3,3
RES share in Gross Final Energy Consumption in %	35,0	38,9
Share of RES in Final Consumption for Heating and Cooling in %	43.0	37,4
Share of RES in Gross Electricity Consumption in %	61,0	62,0
Share of RES in Final Consumption for transport in %	19,0	15,5
Energy Productivity [million € ‘10/ ktoe]	11,0	10,8
Gross Domestic Energy Consumption [Mtoe]	22,2	1,2
Primary energy consumption [Mtoe]	20,6	1,0
Final energy consumption [Mtoe]	17.4	0,9
Final energy consumption without ambient heat [Mtoe]	16,5	0,8
Installed power in GW with fossil fuels-lignite GW	0,0	0,0
Installed power in GW with N.G	6,9	0,5
Installed power in GW with wind turbines	7,0	1,8
Installed power in GW with P/V	7,7	1,4
Total installed power in GW	19,0	3,7
Gross electricity production in TWh	58,0	4,0
Net electricity production in TWh	57,0	3,9
Power production with NG in TWh	17,2	4,4
Power production with biomass in TWh	1,8	0,0
Power production with hydro in TWh	9,3	1,2
Power production with wind turbines in TWh	12,1	1,2
Power production with P/V in TWh	7,6	0,5
Power production with solar systems in TWh	7,2	1,1
Power production with geothermal	1,8	0,4
Net electricity imports in TWh	0,3	0,0
Final electricity consumption in TWh	53,6	2,8
Number of total energy end-users	7.445.000	287.000
Number of buildings have been energy upgraded	610.000	24.543

Source: RAE, IENE and IEA overtime reports.

To this direction, it is important to be given some information about the structural process and degree of countries readiness regarding the transition. The figures below present the structural changes, process and the goals put till 2050 by Greek government. We see the great change that the transition will cause to all economic sectors.

The next figure/chart 5 presents some ideas regarding the transition in net zero-carbon economy in Greek cities being greater polluters from transport means.

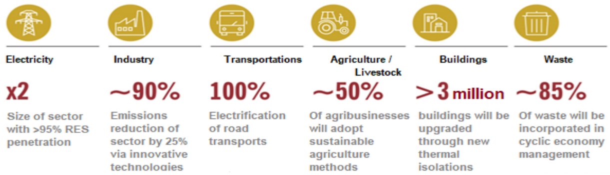


Fig. 4. Structural changes towards 2050 energy transition

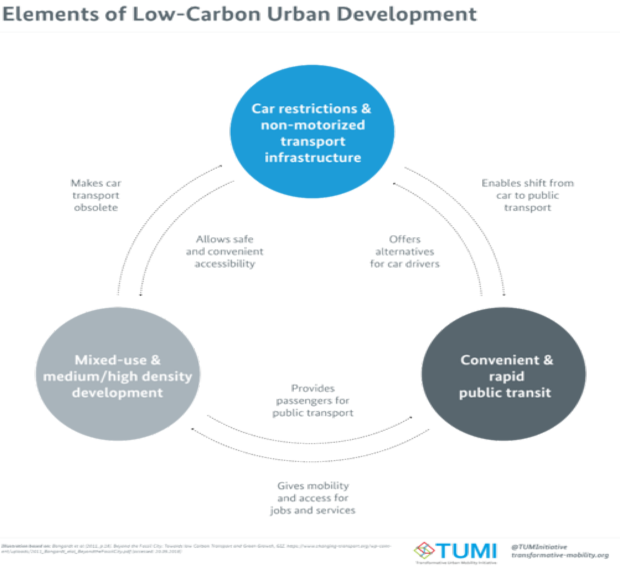


Fig. 5. Elements of low-carbon urban development-source: TUMI 2021.

3. Sub-Part A: Introductive Macro-Approach about the Transition

3.1. Introduction to global challenges in the energy sector

- **First challenge=cooperation:** EU, Greece, REMTH operate in a globalized energy level and any unilateral action may not bring all the expected benefits. There is a need for a broader and more coordinated approach to global energy issues in order the EU to, responds faster and better to global energy and climate changes, addresses issue related to competitiveness and decarbonization more effectively and promotes the highest standards of nuclear safety.
- **Second challenge= energy safety:** EU will have to ensuring a secure and diversified energy supply for all its member states in good prices. The need to ensure its energy security and self-sufficiency, EU has to emphasize, to various energy providers, to high energy saving to high penetration of RES and to introduce everywhere smart energy management tools. It is stressed that, EU energy policy must, in no way, run counter to the basic principles on which the EU is founded, in particular democracy and human rights. EU owes to support the poorer members to improve cost effectiveness of their ES's and to strengthen cooperation with its global strategic energy partners. It is deserved to consider the growing influence of emerging economies on global energy markets, as well as, their growing energy demand, facts that are fully essential related to climate protection. There should be no compromise on the least GHG emissions, safety, and security of traditional renewable sources. For the sake of the global energy system, the EU must continue to play an active-not passive- role in the international negotiations on the global climate agreement and be aware of the consequences of a failure to conclude a global agreement on climate change [120], [121], [116].
- **Third challenge=an effective Emissions Trading System:** European Emissions Trading System (ETS) is the main tool of reducing industrial GHG emissions and promoting investments in safe and sustainable low emission power generation technologies. It is pointed out that, further structural improvement of the ETS is necessary in order to increase the transition plans' ability to respond to economic change, to strengthen FDI security and attracting. Structural changes in the ETS require careful assessment of the environmental, economic, and social impacts, as well as its impact on electricity prices and on competitiveness of energy-intensive industries. It should be noted that, the non-ETS part of industries is responsible for 55% of the EU GHG emissions and, at the same time, it is important to ensure that the non-ETS part also bears its responsibility for emission reductions. It is resulted that, the ETS is facing problems that were not initially anticipated and that the accumulation of CO2 rights surplus will weaken the incentive to promote low GHG emissions investments in the near future. This jeopardizes the effectiveness of the ETS being the EU's key GHG reduction mechanism. So it is needed to be created a level playing field for competing technologies, providing companies with the flexibility to develop their own mitigation strategies and fight against GHG emissions [42], [43], [44], [66], [85], [86], [99].
- **Fourth challenge=research for new power production technologies/methods:** EU has to address initiatives in order to introduce power systems with greater efficiency, min GHG emissions, min variability/stochasticity. They mean a skillfulness manpower with good experience with new technologies for RES and biofuels capable to contribute to faster energy transition. There is a view arguing that the volatile and uncertain price of fossil fuels promotes the faster adoption of RES and biofuels by societies-but this view doesn't adopt by energy experts. EU recommends to its member to promote and support effective plans for new technology off and onshore RES in order to minimize rising energy prices.
- **Fifth challenge= use of higher power production efficiency and saving systems**: in recent years in EU has developed an approach that claims that the increased energy consumption and high prices can be coped with two tools, energy efficiency and saving systems in industry, transportation, and buildings. This concept is based on the role of information and communication technologies (ICT) can play in energy processes and application. ICT, like blockchain, IoT, Machine Learning Algorithms find mane uses in all smart energy networks, in efficient energy consumption systems and, in particular, for the development of intelligent metric/metering systems that provide consumers with data on energy consumption in real time and the potentiality the surplus power to be returned to the network. It is believed that energy infrastructure should be more end-user oriented, with a stronger emphasis on the interaction between distribution system capabilities and consumption facilities, and the need for real-time, two-way energy and information flows [57]. It is stressed that many benefits will enjoy users from new power technologies, such as smart demand/supply management systems that improve energy efficiency for them.
- **Sixth challenge=replacement of old network/grids with new and smart ones with multiple functions:** The development of smart grids is a matter of urgency, because without them, it will not be possible to consolidate decentralized production from RES and improve the energy consumption efficiency. The smart grids facilitate the two-way communication between producers and power consumers and allow consumers to monitor and adjust their energy use on time, while their personal data are protected. EU Members should make information available to clients through websites so that all relevant bodies, manufacturers, architects and suppliers of heat, cooling, and electricity equipment to have access to up-to-date information about prices and services. It must also be ensured that both projects, the "Horizon 20-20-20" and the "European Innovation Partnerships" will run under the "Innovation Union" prioritizing the need to be developed all kinds of low-carbon technologies. This will enforce energy competitiveness in the EU, promoting opportunities for new jobs and motivating for a responsible approach to energy using. The EU must support the objectives of the European Strategic Energy Technology Plan-ESETP and related European Industrial Initiatives in this context. The highest priority must be the higher energy efficiency and the lower cost of new technology/higher performance RES. It means larger share of public budgets on financing innovations in RES and energy efficiency research. Yet it is needed better exploitation of Horizon 20-20-20 and Save Energy in Textiles (SET) projects [36], [50].
- **Seventh challenge= doubling of money for R&D in RES technologies:** Many experts stress the need for further intensive R&D in RES technologies to improve their efficiency and CAPEX. Also, since NG/LNG will continue to be used till 2040 in power production, vehicles, shipping/air transport, and heating/cooling countries will have to invest in smart pipeline systems that

will reduce the distribution cost significantly (IEA-Energy Efficiency Report 2019). Energy policy makers will have to urge the relative bodies to increase funding for smarter local energy infrastructure, replacing gradually old technology infrastructure. The previous point out that, readily available RES solutions, along with, measures enforcing energy efficiency and plants co-generating heat and power will give regions the ability to rid carbon footprint of all heating demand by 2050 [98], [104].

In conclusion, the complex relationship between energy, environmental, societies and economies require adhoc measures and approaches in order the pre-set decarbonizing goals to be 90-99% achievable. Yet, the 273 EU regions will have to follow in general a common transition roadmap, adapting of course the general directives to their own particularities. Each region should be able to pursue an individual tailor-made plan according to its economy and energy production structure, developing faster sustainable energy sources and smarter infrastructure that can more effectively meet the objectives of the energy roadmap up to2050. Our model proposes actions, works and infrastructure based on both, global bet practices and Greek official roadmap 2020-2050 report able to promote a cost- effective transition and aims to introduce the reader to how, when, and why of transition roadmap and to understand the future structure and operations of energy system and positive impacts on climate.

1. Since it is predicted power consumption of households will be doubled by 2050, while the demand by industry/transport will be dramatically increased. Transport and buildings' heating/cooling will be electrified by 90%. So, new power sources will have to be installed ensuring energy supply safety.
2. P/V-W/T will produce after 2030 cheaper power than existing NG/LNG plants by 25-35% due to new technologies. This will trigger a sharp uptake in the installed capacity of offshore P/V-W/T systems. It is forecasted that more than 7 TW capacity of RES will be installed by 2020- 2050.
3. Energy efficiency WILL increase by 60% till 2050 due to technological advancements in RES performance.Electric vehicles will cover an 80-90% of total vehicles sold till 2050 that will consume 35-50 % less energy than today.
4. Energy consumption per capita drops by 5% globally till 2050, despite strong economic development that affects billions of emerging economies. The next figure outlines the restructuring and upgrading of Greek ES and its impact on climate.

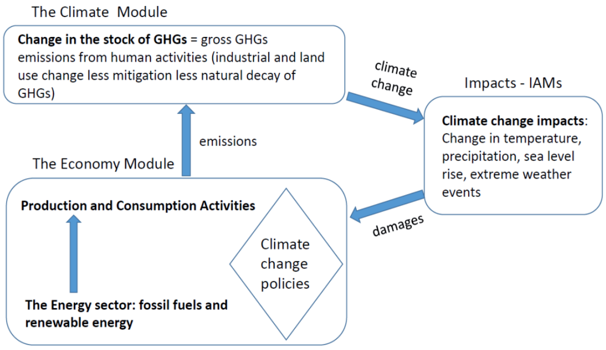


Fig. 6. The climate module and energy implication, Source: IRENE report 2020, Bank of Greece, 2018**.**

3.2. Energy Systems and Markets: their role toward the transition

3.2.1. The general framework of EU transition roadmap toward 2050

The Energy Roadmap to 2050 (ER-2050) of the EU shows that a carbon-free future and a RES-based economy are by 98% possible developments. Kapros P (2020/NTUA/RAE), based on the PRIMES model, claims that EU ER-2050 is a realistic effort combining the goal of transition to a carbon-free economy with security of supply and energy competitiveness. The ER-2050 report analyzes different scenarios for Europe's ESs and shows that a RES - based future has no greater cost than continuing to depend on fossil fuels, or nuclear energy. Also, ER-2050 provides an answer to the question, "what energy strategy will the EU pursue after 2020" and five scenarios have been proposed:

1. **Scenario of Increased Energy Efficiency**: assumes as a working case the undertaking of political commitments for very high levels of energy savings through measures such as, stricter minimum requirements for appliances and buildings, predicting a reduction in energy demand by 41% till 2050 compared to the highest level observed in period 2005-2006.
2. **Scenario of Differentiated Technologies**: refers to an economy in which one energy technology does not excel over others. Each form of energy can compete with the others in market conditions, without particularly supportive measures. GHG emission reduction is promoted through high taxing of carbon with acceptance of both, nuclear and CCS energy technologies.
3. **Scenario of RES as basis of energy autarchy**: provides strong incentives to RES that lead to an increase in their share of final energy consumption, around 75-95% . In this scenario, nuclear power and coal shrink below 1,5% and 1,0%, respectively, of energy production.
4. **Scenario of Carbon Capture Storage-CCS**: it is similar to 2 one, except that it requires a larger share of nuclear energy, and it contributes to GHG emissions reduction due to rising of CO2 prices, rather than to technological advancements.
5. **Scenario of Nuclear Energy Low Involvement**: similar to 2 one, except that it requires a zero-increase in nuclear power use, excluding reactors under construction. It leads to an increased share 32% of CCS mix in power generation. European Wind Energy Union (E-WEA) emphasizes on the goal "power generation by 2050 to be based 95-100% in on/offshore RES, since this option is the most cost-effective.

Summarizing the ER-2050 Roadmap report, we result to next basic views of E-WEA regarding its key-goal for a cost-effective transition pathway for all members [37], [56]:

1. **Pursuing mutual benefits:** EU members work together as a pan-European government to transform their energy structure and systems. Setting the common energy targets for 2020-2050 can together to achieve huge benefits an economies of scale.
2. **Approving a common basis for the submission of legislative and other energy policy initiatives:** with a view to developing a common policy framework that

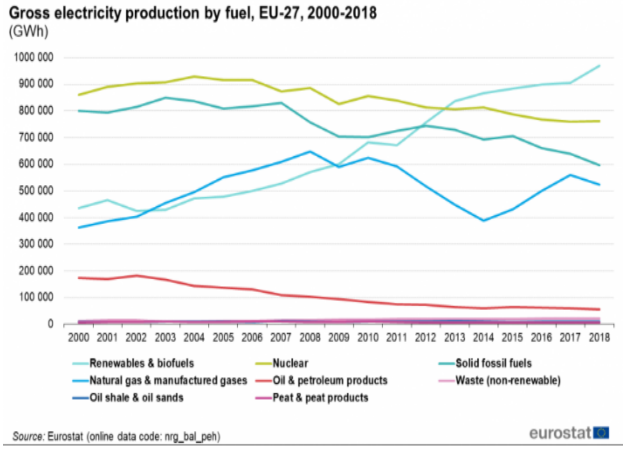
includes, targets for GHG emissions, share of RES, and increased energy efficiency

3. **Proposing general transition guides for all and adhoc transition scenarios for each member:** the 2050 is a symbolic milestone but not deterministic for final transition. It consists of the basis for a constructive dialogue on how to be transformed EU energy system in order to achieve the long-term goals of reducing GHG emissions till 2050 by 80% regarding the 1990 and 65% compared to 2005 level. Probably, if forecasts are based on erroneous assumptions about technological and economic developments then EC has to make the proper intervention and update the roadmap- rolling energy plan.
4. **Models will have to be based on AI/ML advance algorithms for greater accuracy:** They have to be flexible, and easily parametrizing so that their upgrading to be a routine for energy experts. All scenarios in modeling have to aim to, further GHG reduction, secure energy supply, flexibility in EU ES's and all relative projects will have to be compatible to key-goals of ER-2050.
5. **Plans for cope with the post-covid 19 era:** EU have to see again the role of energy in, promoting higher growth rates and competitiveness, creation new well-skilled jobs, drawing smart growth strategies for the period after 2023 and taking into account all the negative impacts of covid-19.
6. **Plans for cope with the energy poverty in EU:** since the energy poverty is at least to 20% of the population, EU has to cope with this fact ensuring low electricity prices for those end-users can't pay the energy.
7. **EU urges states/regions to follow the general Roadmap-2050 after the necessary adaptations:** it means every state/region will have to adapt the general plan to its adhoc needs in order to ensure energy security by developing the RES with the most efficient way.
8. **EU will have to consider the transition as a jump to a more competitive sustainable growth:** energy transition to a more efficient and zero GHG economy is an opportunity for both, sustainability and security of supply. Lower emissions can be a competitive advantage in the growing energy markets for energy products and services-promoting the brand=batter goods with lower energy embedded. Such policies should boost the highest potential entrepreneurship and innovation.
9. **Reorganizing EU energy markets based on zero carbon production systems:** it will point-out that new energy markets implies lower prices so energy will can play an important role in promoting a more competitive growth and will determine the behavior of market players, including industry and consumers.
10. **Pursuing energy self-efficiency till 2040:** the target is ESs of EU Members must be based on own energy resources of more than 85% till 2040. Countries must soon develop sustainable energy technologies which will ensure a continuous and stable energy supply, with almost zero variability/stochasticity along with the respecting of standards leading to environment and climate protection. In energy planning the approaching "top to down" has to be in balance with the "bottom-up" one, so strong synergies and complementarities to be yielded.
11. **The targets of "Roadmap- 2050" and necessary conditions to be achievable:** it means that if the EU does not play an active role for an effective transition, pushing and monitoring members- especially whether they implement in due time their large-scale projects and actions, then the targets will late. The more cooperation and synergy, the better transition results.
12. **All members have to pursue the best power mix:** it means all countries will pursue to make a mix where the RES will prevail , but the share of each RES technology depends on each country's shiny/windy/geothermal/Hydro conditions. For Greece it means higher percentage of P/V and W/T and lower ones of geothermal/hydro.
13. **Energy Storage Technologies as key-tool for transition:** EU members in order to increase their E.S flexibility/effectiveness should explore potential new energy storage technologies, that can counter-balance the supply variability owed to high penetration of RES-more than 90% till 2050.
14. **Replacing of old networks and grids with new smart technology ones:** it means better exploitation of grid capacities and opportunities for end-users to enjoy clean energy in lower prices. It is suggested members to reduce their energy dependence from import NG/LNG and create a truly single European energy market with the greatest possible security and clean power supply in future.
15. **Considering financial and health crises as a great challenge for transition and not as obstacles**: Europeans have to see these two huge obstacles as an opportunity to transform their economy structure and growth model towards an energy economy based entirely on new technology RES produced in-home in EU.
16. **Simplifying of administrative procedures about the transition process:** in many members the institutional context for transition is very complex and red-taping and it has to be simplified and more cost-effective. Greater penetration of RES in energy mix needs simpler and flexible institutional environment. Red-tape is a subset of regulation that imposes undue, excessive compliance costs and distortion to the energy markets. It is estimated that the complex institutions burden the RES penetration with a 7,3% additional useless cost(support institutions that can be adapted over time and gradually de-escalated when new technologies mature and become cost competitive and market failures reduced dramatically.
17. **Promoting the small RES producers for increasing their share in the energy mix:** small RES producers have some competive advantages such as, dispersed RES, low overhead costs, contribute more to local development than greater producers, increase energy efficiency, ensure better energy supply security and active involvement in combating climate change.
18. **Promoting the crossborder energy cooperation:** since power production implies pollution through GHG emissions, therefore no borders for gas polluters, the tight cooperation is necessary. Energy policy decisions have to take in account and this serious parameter.
19. **Promoting best project management techniques for the transition:** Energy infrastructure projects are characterized by huge front-end investments that will be significantly reduced with the full utilization of projects to their ending- operating life of 30 years. The current energy environment is unpredictable and, therefore, investors are reluctant to construct new high cost energy infrastructure. Therefore, new strategies and innovative project management tools needed to decrease the time and money for implementation such transition projects.
20. **Promoting best coordination of energy markets and their adaptation to Target Model and F-55 Model of EU:** EU energy markets will have to adopt the above two

models that contribute to unify energy markets and increase their competitiveness. Yet, these models play a key-role in attracting investors wishing to invest in energy smart infrastructure. It happens because investors feel greater secure for their investments under the conditions ensuring the above two models. The less liberty markets the less attractive for serious investors.

21. **NG/LNG will have to remain as power fuels till 2040 for security reasons:** EU, after Russian-Ukrainian crisis recognizes that, despite the high dependence of EU from Russian NG, this fuel will continue to play a great role in transforming its energy systems during the green transition, as it represents a rapid, temporary, and cost-effective way to reduce the use of other more polluting fossil fuels. Simply, EU have to diversify NG providers.
22. **Carbon Capture, Utilization and Storage (CCUS) will have to play a key-role in energy transition roadmap:** EU have to move towards 2050 and get-rid of GHG emissions, will have to use the CCUS technologies-new tools and technologies need to evolve to fully plan and monitor CCUS wells- in large scale so that to support the transition to a zero-carbon economy. It should reduce the necessary transition time by 15-17% and cost by 10% (Source: https://www.energy.gov/articles/us-department-energy announces-131-million-ccus-technologies),
23. **Oil refining industry and its temporally contribution to transition process**: Despite that EU members will desire to stop using oil in buildings' heating systems and transportation, there is still a strong demand for oil, and therefore it is important to maintain a 33% of the European oil refining industry till 2030. It is necessary for ensuring security of supply, supporting the competitiveness of the petrochemical industry, and setting strict global standards for refining fuel quality in compliance with environmental rules.

In conclusion, each state should choose its own energy transition mix according to its peculiarities, of course based on the general framework of EU transition roadmap. EU transition roadmap encourages and support members to speed up their ongoing efforts for a cost-effective transition. In order to take a picture regarding the EU members about the transition process, we benchmark and compare the total existed and projected reduction of CO2 emissions for the years 2020, 2030. The result is an estimate of the annualized total and marginal capital cost of abatement, respectively and the figure 7 and the table 4 below summarizes the results [41], [45], [75], [76], [77], [78], [105].


Gross electricity production by fuel, EU-27, 2000-2018

Source: Eurostat (online data code: nrg_bal_peh)

Fig. 7. Installed RES and fossil fuels capacity in EU- 28, Source: Eurostat 2018.

Table 4. Basic futures of EU ESs and a Descriptive Statistics of the used variables per country Source: IEA report 2020 - EUROSTAT 2020

Country Name	Energy Consumption	CO2 emissions	Energy Intensity	CO2 Emissions	Carbonization Index
Austria	2600.4-(47693.5)	54466.25-(8388.35)	0.131-(0.015)	0.281-(0.048)	2.121-(0.179)
Belgium	50573.84-(6600.76)	107773.33-(8308.43)	0.207-(0.031)	0.459-(0.136)	2.170-(0.319)
Bulgaria	27150.56-(2428.19)	55910.65-(9748.96)	0.471-(0.144)	1.144-(0.405)	2.401-(0.174)
Cyprus	1479.46-(686.32)	4734.95-(2770.94)	0.152-(0.025)	0.572-(0.746)	3.771-(4.955)
Czech. Rep	45095.32-(3044.22)	142796.13-(23808.33)	0.282-(0.052)	0.909-(0.265)	3.151-(0.386)
Denmark	18967.23-(1076.395)	55137.36-(5271.29)	0.148-(0.035)	0.434-(0.122)	2.901-(0.203)
Finland	28199.45-(5860.18)	51524.26-(7000.45)	0.256-(0.026)	-0.485-(0.106	1.874-(0.234)
France	220195.63-(36645.11)	379257.71-(39869.17)	0.161-(0.016)	0.297-(0.108)	1.800-(0.475)
Germany	338290.71-(14972.95)	922027.12-(102619.14)	0.178-(0.043)	0.498-(0.173)	2.721-(0.298)
Greece	20589.11-(6895.36)	63247.09-(22174.61)	0.103-(0.014)	0.321-(0.055)	3.082-(0.122)
Hungary	26081.72-(2920.16)	62318.12-(9480.08)	0.214-(0.035)	0.521-(0.138)	2.394-(0.289)
Ireland	104.82-(3002.55)	32083.65-(7864.43)	-0.154-(0.044)	0.488-(0.164)	3.124-(0.182)
Italy	146708.64-(23314.23)	373655.32-(43724.96)	0.116-(0.013)	0.301-(0.046)	2.573-(0.132)
Luxembourg	3640.39-(507.81)	8117.01-(1588.32)	0.251-(0.131)	0.542-(0.261)	2.224-(0.201)
Malta	576.69-(243.48)	2327.05-(3548.97)	0.123-(0.029)	0.449-(0.371)	3.784-(0.980)
Netherlands	67683.18-(8372.26)	160428.61-14888.84)	0.174-(0.033)	0.416-(0.091)	2.382-(0.112)
Norway	21713.37-(5078.58)	29929.15=(5786.19)	0.152-(0.021)	0.217-(0.046)	1.409-(0.120)
Poland	104708.88-(14347.55)	351838.12-(60395.82)	0.294-(0.093)	0.997-(0.347)	3.345-(0.151
Romania	50039.73-(11943.09)	127064.91-(37390.44)	0.323-(0.088)	0.817-(0.255)	2.488-(0.181)

Slovakia	18324.25-(1801.16)	42485.72-(7610.67)	0.288-(0.058)	0.686-(0.207)	2.333-(0.338)
Spain	92014.84-(31737.66)	217096.31-(66670.51)	0.114-(0.006)	0.276-(0.024)	2.240-(0.171)
Sweden	46106.01-(4942.29)	57070.33-(14640.01)	0.223-(0.033)	0.298-(0.145)	1.285-(0.477)
UK	209465.41-(10344.22)	555529.61-(34915.08)	0.161-(0.041)	0.435-(0.141)	2.651-(0.205)

3.2.2. EU energy markets and their roadmaps to be unified-Profits/losses for Greece

Till the 1990s, power companies in Europe were state monopolies having the right to supply energy exclusively to consumers. These exclusive rights posed great obstacles to the creation of a common energy market-CEM. The process of creating common power markets began in 1992 with the European Commission formally proposing the first package of Electricity Directives. The first common rules concerning the power production operation, transmission and distribution networks were laid down in Directive 96/92/EC in 1996, with the following key points [38], [40]:

- Abolition of exclusive rights and liberalization of electricity production.
- Establishment of an independent licensing and monitoring body the energy markets.
- Establishment of an independent Transmission System Operator (TSO), for the control, maintenance, and possible development of the electricity transmission network.
- Provision for control and resolution of disputes in the internal market in order to avoid abuses of monopolistic positions.

In order to improve the performance of energy markets, a new Directive (2003/54 / EC) was issued by EU and adopted by members in 2003, which:

- Extends markets liberalization for non-household users by 2004 and to all customers by June 2007.
- Adopts measures for the legal separation the transmission from distribution networks and administrative management from the production/supply power activities.
- Strengthens the role of Members Energy Regulators.
- Strengthens useful services of general interest for societies.

In 2009, the third Directive (2009/72/EC) was adopted, which is part of the Third Energy Package and aims to:

- More cost-efficient separation of transmission system operators-TSO from power generation or supply activities.
- Facilitate cross-border energy trade, investments, and promotion of regional cooperation.
- Achieve greater market transparency to operation services like, the grids and the supply of electricity.
- Ensure the effectiveness and independence of national energy regulators-NER.
- Increase solidarity between EU Members and organize cooperation at EU level between NER and TSO.

In 1999 was establishment the European Transmission System Operators-ENTSO, and it is developed in 2008 into ENTSO-E and it is considered as an important milestone.

Agency for the Cooperation of Energy Regulators (ACER) was established in 2010 having as headquarter Slovenia. [38], [46], [47], [48]. The same period the climate and energy package was issued by EC 2020 promoting the first measures for better climate, calling target 20-20-20 and meaning: 20% cut in GHGs emissions from 1990 levels, 20% of EU energy will come from RES, 20% improvements in energy efficiency. The strategy to achieve the objectives of the EU Green Deal contributes to climate protection by 2050 since energy production and consumption account for 75 % of GHGs emissions. The figure 8 shows the share of RES in power mix of EU members as this index is the more representative and serious of target for the year 2020.

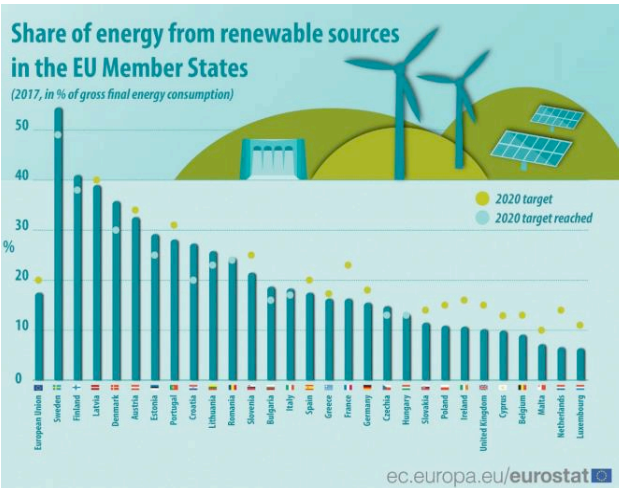


Fig. 8. Share of power from RES in EU countries – 2020, Source: EUROSTAT 2021 report.

3.2.3. Structure of Greek/REMTHs Energy System-ES

The today structure of Greek energy market is based on EU guidelines, meaning that energy market is almost fully liberalized. The last European Target Model (TM) for the reorganization of the electricity markets has imposed dynamic structural changes in operation of national markets. Electricity, as a special good, is divided into four distinct operations, production, transmission, distribution, and supply. These fore functions ruled by adhoc bodies having the form of Independence Legal Entities Due to introduction of T.M (2020) in Greek energy system, the institutional and economic changes are introduced and carried out gradually. Some practical problems emerged and owing to the way the energy market liberalized, are solved, and incorporated to E.S gradually [38], [106], [122]. The key-changes of the Greek ES are the laws: 2773/1999/165, 3426/2005, 4001/2011, 4425/2016 and 4512/2018. These laws establish the next Independent Authorities (IA):

- **Regulation Authority of Energy -RAE:** its responsibilities are "to monitor and control the operation of the market in all its aspects and to suggest to the competent bodies for taking of the necessary measures to comply with normal competition rules and to protect consumers ".
- **Electricity Transmission System-ETC:** it belongs to Public Power Corporation -PPC and responsible is to manage the transmission operation.

- **Hellenic Electricity Transmission System Manager - HETSM:** its responsibilities defined by adhoc law giving it the exclusive right "to, operate the ETC, take care of the development of the ES throughout the country, as well as its interconnection with other networks to ensure the electricity supply to all users in an adequate, safe, cost-effective and reliable way.
- **Origin Guarantee Manager- OGM**: it is responsible for the Register of Electricity Market Participants-REMP and conducts the Daily Energy Planning (DEP). OGM ranks bids in ascending order, based on price and then schedules the load to the next day. The most cost supplier taking part in the ES, forms the final price in the daily wholesale electricity market and is the price at which producer are paid and it is called Marginal Price of Systems-MPS.
- **Hellenic Energy Exchange-HEE SA:** is the body for the operational management of the Hellenic Energy Exchange-HEE. Through HEE are arranged the final prices for the next day and the intraday.

Table 5 presents schematically the new legislative framework that was adopted for the restructuring of the Greek Energy Market, according to the rules of the "Target Model" ruled by L.4425/2016, as amended by L.4512/2018 [38], [52], [53].

3.2.4.The key-climate problems in European Union and an approach to be solved

The new researches warn politicians and energy decision makers that climate change and extreme weather events increasingly affect all parts of the European energy systems. The most important changes are referred to, serious increase in air and water temperatures, changes in water availability, extreme climate-related phenomena, and coastal hazards. These changes will affect the availability of primary energy sources, especially RESs, as well as the production, supplying, transmission, distribution, and storage of energy. The climate changes impacting on the spatial energy systems can be, either beneficial like, reduced energy demand for heating/cooling of buildings, or negative for the energy sector and the society as a whole. Such negative impacts include reduced cooling water availability for thermal power plants and reduced water availability for hydropower production and increasing risks for energy infrastructure from extreme weather phenomena. According to the European Environment Agency-EEA report(9/2019), climate change impacts and related necessary adaptations vary significantly across European regions. Northern European regions experiences beneficial and adverse impacts on its energy systems, whereas central and southern European regions face overwhelmingly adverse impacts by 75-80%. The evolving policy context under the Energy Union provides unique opportunities for mainstreaming climate change adaptation in European Union energy planning. The assessment suggestions considering the impacts of climate change in the development of national climate/energy plans and long-term strategies under the EU Energy Union.

Table 5. The structure and operation of Greek energy markets.

Markets type	**Spot markets**			**Derivative markets**	
Functions	Day ahead	Intraday	Balancing	Physical delivery	Cash settlement
Trading	Energy exchange	Energy exchange	ADMHE	Energy exchange	Energy exchange
Clearing	Energy clear	Energy clear	Energy clear	ATHEX clear	ATHEX clear
Settlement	Energy clear	Energy clear	ADMHE	ATHEX clear	ATHEX clear
Technical and operation support	ATHEX	ATHEX	ADMHE	ATHEX	ATHEX

Source: Greek Regulation Authority of Energy-RAE report 2002-2020.

Yet, market players in the energy sector should consider strengthening climate resilience as an integral part of their normal business. EU Energy Union concludes to the next findings:

1. European energy system increasingly needs to adapt and become more climate-resilient in the frame of gradually climate change. Societies' increasing dependence on a reliable and cost-effective energy supply and an increasing share of climate-sensitive RES.
2. The development of the EU Energy Union aims to make energy more secure, affordable, and sustainable, providing important opportunities for further integrating climate change adaptation in EU energy planning.
3. Climate change and extreme weather increasingly impact all components of the ES. Both affect the availability of primary energy sources, the transformation, transmission, distribution and storage of energy, and energy demand by all users. It is crucial that these impacts are considered in the clean energy transition roadmap.
4. Some energy utilities, grids providers and energy stakeholders are already addressing adaptation needs. All market players in the energy sector, including enterprises associations, should consider strengthening climate resilience as an integral part of their business.
5. Most EU-countries have dealt with the energy issues in national climate change impact, vulnerability, and risk assessments, doing the national adaptation strategies and action plans. Governments can further facilitate adaptation through the necessary regulation of energy markets and other policy interventions. [2], [9], [28], [33], [58], [60].
6. The today big problem with RES is that their net efficiency is even now low, ie they require a large percentage of incoming energy to deliver some outgoing energy greater by 20 -50%, unlike fossil fuels with efficiency 80-95%. Yet, in EU the average share in power mix of other RES, hydroelectric, biofuels and geothermal is relatively small, only 10,8%.
7. Nuclear fission energy is not the best answer to replace NG/LNG, which currently provide in EU about 22,0% of energy demand. Unlike nuclear fission, nuclear fusion does not produce radioactive waste or GHG in the long-run and would allow the production of huge amounts of clean energy by merging Deuterium abundant in the oceans and Tritium-derived by Li6-but this technology is up today an utopia.
8. A more optimistic medium-term scenario is the production of green H2 from RES [2], [9], [28], [33]. The recent orientation of green H2 production from

electrolysis is generally supported, as it can be produced from various raw materials using a variety of processing technologies, aimed at its integration into energy and industrial infrastructure. Electricity generated by P/V, W/T and nuclear plants can be used to electrolytically produce H2 from water. In particular, sunlight can be used to produce H2 from water, using photoelectrochemical and photobiological processes. But H2 production from RES is uneconomical for the time being.

9. The latest research of US Department of Energy (DOE 2020) concludes that. today the cost of H2 production associated with carbon gasifying and CO2 capture (CCUS) methods does not exceed $2 /Kg. The cost of H2 production from nuclear, or wind energy ranges between $ 5,5-6,5/Kg, while from solar electrolysis it reaches $ 14.5/Kg. This cost is equivalent to one $ 687/barrel. Much of the fossil fuels cater to transportation and the main idea for replacing diesel vehicles is to use electric vehicles, and this trend will continue after 2021. Throughout the life cycle of electric vehicles they consume significant amounts of energy. But when this energy comes from RES and not by fossil fuels, they contribute to the reduction of CO2 emissions. Conclusively, the energy transition for near future has to be based on new technology RES and green hydrogen and the more far future in nuclear fusion [28], [58], [60].
10. Climate change as an undesirable fact and the necessary for EU members to adapt their path to common target and strength climate resilience will have to dominate in EUτthe current decade. All parts of the energy system, from energy production and transformation through to transmission, distribution, storage, and demand, can be strongly impacted by long-term climate change. The EU is building late, but stably the Energy Union, which aims to make energy more secure, affordable, and sustainable.

3.2.5. The European Emissions Trade System-ETS

With the ETS launched by EU in 2012, has created a unified energy market mechanism that gives CO2 a price and creates incentives to be reduced emissions by the most cost-effective manner. It has successfully brought down emissions from power generation and energy-intensive industries by 42,8% from 2005, year where ETS was launched. Under the ETS , companies have to hold allowances corresponding to their CO2 emissions, making power production from fossil fuels more expensive and clean power sources more attractive. At the same time, firms are incentivized to become more energy efficient because they can then sell their emissions permits on the market. ETS sets limits on the CO2/GHG emissions by energy-intensive industries, electricity producers and airlines. The ceiling put is reduced over time, in order EU to gradually reduce the total emissions from every production system. Yet, in recent years, the financial crisis has automatically contributed to reduce emissions due to lower power demand from users. This fact in the period 2019-2021, along with other factors, contributing to lower GHG emissions, resulted in lower coal prices. Thus a large surplus of allowances was accumulated in the ES, with the risk of no longer providing incentives to firms to reduce their emissions in a cost-effective manner. Reducing GHG emissions in the EU by at least 40%, 65% and 95% by 2030, 2040, 2050 compared to 1990, is one of the goals agreed by the European Council, as part of the climate and energy framework. In 2015, the EU introduced changes on ETS aimed at encouraging innovations and the use of low-emission GHG technologies despite they were very expensive to create new employment and growth opportunities, while maintaining safeguards for the competitiveness of European industry. In the EU about 6,3 billion CO2 rights, worth up to € 160 billion, are expected to be distributed free of charge to EU companies between 2021 and 2030 - Greece gets 200 million rights worth up to € 5.1 billion, about € 510 million/year. Whereas the ETS is the main instrument for achieving this goal, after five year experience, experts consider it needs to be reformed in order to become more cost-effective, ensuring the proper functioning of the ESs. As a first step towards reform, the EU recently adopted a decision to create a Reserve Fund for the stability of the emission allowance market in the EU against the imbalances between supply and demand. Key philosophy is “the company polluting less, will profit from this transaction”. The figure below explains the ETS.

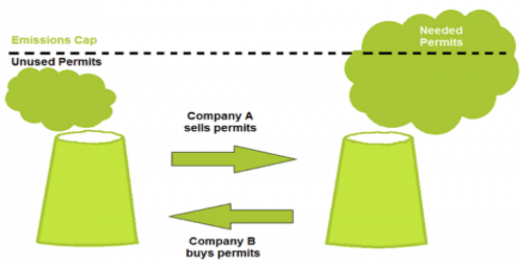


Fig. 9. ETC process-Source: Energy Royd, 2013.

The EC/EU is also proposing to set up various financial support mechanisms to help the power industry to meet the new challenges of innovations, technologies, and investments to be faced effectively the challenges, . Among financial support mechanisms three are the most serious [115], [122], [123], [124]:

- **Innovation Fund**: aiming to boosting innovative plans for introduction of new technologies in all energy sectors involved directly/indirectly/ to energy production and use.
- **Energy production systems modernization Fund**: aiming to facilitating large scale investments in the modernization of the EU Member energy sectors.
- **Green Fund**: financing actions to develop sustainable low carbon and environmental economic aiming to promote activities for strengthening and gradually diversifying positively the local economies and creating good new jobs. Yet this aims to support energy best practices transferring among companies in/out of EU countries.

3.2.6. The ETS and its impacts on Greek energy systems and markets

The EU rules for fair allocation of free allowances among members and polluting firms have imposed a rather good harmonization so that neither country to be unprivileged. So, the changes of ETS in Greek energy system based on grandfathering system and key-goal is to uniform distribution /benchmark emissions. Auctions have become the main method for allocating allowances, among Greek firms, while adhoc measures were instituted to reduce the accumulation of surplus allowances, by significantly reducing the number of allowances, provided to facilities that have greatly reduced their production. It is noted that, new economic sectors and gases were comprised in ETS. Although the ETS is a smart cost-effective mechanism for reducing GHG emissions, its application in micro-spatial basis, Greece/REMTH, poses a risk of CO2 leakage, as non-GHG pricing areas gain in terms of competitiveness against those areas to which are applied standard carbon taxes. The carbon leak, resulting from the asymmetric application of coal pricing measures that nullifies the environmental benefits of the effort to reduce emissions. It is leading only to be transferred economic activities and jobs between regions. The allowances are allocated on the basis of benchmarks, meaning allowances were determined by the average emission intensity of 10% of the facilities, with the lowest emissions per sector during the previous phases of ETS. This is very negative for Greek firms' cost competitiveness for many reasons related to their small size and sectoral structure. In Greece 19 of the 20 firms, or 95%, enjoy fewer rights than they would enjoy if they had the Reference Emission Intensity-REI rating. The REI of electricity production is measured in kg CO2 equivalents (CO2eq) / MWh) and can be used as a key-measure to compare the specific GHG emissions of proposed emission mitigation. . The REI based allocation method presupposes primarily smart incentives facilitating transformation of spatial production systems according to best available practices and standards. An indicative measure of REI is LCOE of a certain power production technology. It can be calculated using data on all cash flows that occur during its lifetime, as well as on the amount of energy that is provided by the respective technology. Cash flows are presented in some aggregate form based on widely deployed monetary accounting principles combining cash flows into different categories of expenditures and revenues that occur at varying points during the lifetime of the investment-data from DEDDHE. Auction revenue from the existing ETS go mainly to Greek budget and is used to tackle climate change directly or indirectly. Under the existing ETS, Greece is required to spend at least 50% of their auction revenue to support GHG emissions reductions, to support RES penetration and carbon capture and storage, and to improve energy efficiency. Rising carbon prices in the existing ETS since 2018 to 2022 by 64,2%, have brought about an increase in the auction revenue available to spend on climate action. In 2018-2022, revenues amounted to €450-620 million/year. The extent to which Greek firms pass through such CO2 costs under the ETS is a question at the core of the analysis on carbon leakage* and firms' profits – the latter with implications for the distribution of economic surpluses among producers and users, and also between sectors regulated by the ES. On average, Greece has the follow data concerning ETC:

- It spends 70% of ETC revenue for climate/ energy-related purposes and 30% for the rest ones.
- It poses the 3rd best performance among the EU-27 attaining reductions in the ETS sectors of 56.3% in 2020 compared to 2005- Denmark (-58.3%) and Estonia (-56.4%) performed marginally better.
- Its emissions is greater due to the decline, particularly in 2019-2020, in lignite-based electricity generation, which in 2020 emitted 14 million fewer tons of CO_2 compared to 2018. So, Greece noted the greatest % reduction of emissions from fossil fuels among the EU countries compared to 2005 (-78.9%).
- This reduction of emissions from lignite was followed by an increase in emissions from NG (+44% in 2020 compared to 2013. Also, 2020 was the first year, when emissions from the energy-intensive industry (11.5 million tons) surpassed those from lignite (9.2 million tons)

To the next we give some financial impacts of ETC to Greek economy.

Table 6. Financial impacts of ETC to Greek economy.

Impacts in/on	**Description**	**Quantitative expression %**
Investment and innovation	Impact on investment has been small so far, CO2 has now become a part of the investment appraisal of power sector construction	22,4
	Innovative activities in a number of sectors both within the EU ETS driven by the carbon price directly, and in sectors outside, for which the potential to sell offsets into the scheme was driving innovation	43,2
	A part of firms pursued some measures to reduce GHG emissions	13,1
	Limited impact on innovation due to its lack of stringency in its early Phases and its lower importance than other context factors	11,3
Total		100,0
Firms' product prices and profits	Some firms absorbed the cost by reducing profit margins	16,7
	Some firms decreased costs by improving the efficiency of their operations	24,3
	Some firms passed the additional costs onto the end-users/ consumer	59,0
Total		100,0

Source*:* Trends in the Emissions Trading System in the EU and in Greece- Green Tank report 2022

To the next we give some additional information regarding the ETC impacts on Greece economy and power production competitiveness. In 2021 price of CO2 had rosed on the EU stock markets, a bad development that increased costs for polluters in Greece/REMTH. ETS is the key-tool for the drastic reduction of GHG emissions in Greece that cause climate change, as it obliges all polluters, power plants and industries to buy rights for each ton of CO2 they emit. The prices of its carbon rights rose in average terms to 54,25 €/ton from 23,05 €/ton in October 2020, which means an increase of 134,6%. Some analysts predict a raising of CO2 price to 89

***Carbon leakage refers to the shifting of productive capacity from one country to another as a result of differential emissions pricing policy It is nowadays common to distinguish 'investment leakage' where new investments in energy intensive production facilities take place outside of a carbon pricing zone such as the EU ETS, and 'product leakage' where the share of EU producers in both export and internal markets diminishes. This distinction, however, remains fuzzy because in the end 'investment leakage' must translate itself into 'product leakage' and vice versa. Two channels of carbon leakage have also been discussed: decreasing market shares and profit margins**

€/ton by 2022, in order to support the drive to reduce emissions by 65% till 2030, a fact necessary for climate protection but catastrophic for the competitiveness of the Greek economy if it does not make the technological and structural adaptations and changes. This great increase in the price of CO2 tax for pollutants has a decisive effect on the Greek energy market, as it has an increasing effect on the cost of electricity generation by 11,3%. The increased prices of tax for pollutants have a positive effect on the revenues from the auctions of GHG emissions rights, which, at a rate of 78,0%, are channeled directly to support RES penetration. In 2021, the distribution of emission rights was completed, resulting in the collection of over € 641 m. Finally, the quantification of the effects of ETS on the Greek economy-about the same to REMTH's- from the passing of the additional cost from CO2 emission allowances to electric prices, which causes an indirect cost to total productive economy is presented to the table below.

Remark:
The effectiveness of ETS and other such flexible environmental mechanisms have been strongly challenged by a number of scientists and environmental organizations (NASA, James Hansen Scientific Reticence: A Threat to Humanity and Nature, 11/2017). Criticism focuses on the paradox of the system, which has already created a stock market bubble, full of ecological sensitivities. The lower the emissions that are supposed to be the target of the CO2 tax, the lower the value of pollution rights.

Table 7. Impacts of ETS in Greece economy.

Field was impacted	Description of impacts	Estimation by %
In growth rates of GDP yearly	Since positive impacts are greater than negative the final impact will be positive	0,3
In competitiveness of total economy	In initial phase it will be decreased and to mid-macro term basis it will be increased	-1,0 to 5,0
In increase of domestic added value	In mid-macro term basis it will be increased because RES systems are high tech energy equipment	22,0
In increase of employment	Initially during the construction period it will be increased, after that will decreased but in mid-macro term basis it will be increased slowly but with stable rate.	-10,0 to 15,0
In electricity price	ETS impact was small because Greece carried out a smart system of emission rights	-1,0 to -2,0
In income distribution-Gini Index	Even if energy taxes are a cost-effective tool, its cost-sharing is an important factor in determining its acceptance. The results of various surveys on the effects of energy taxation on income distribution are ambiguous, so we consider them neutral	0,0 to 1,0
In GHG emission reduction	ETS has strong positive impact on GHG reduction comparing to 2005	Around 25,0

Source: RAE, IENE reports 2022

3.3. Innovations and new technologies in energy systems and their impact on cost-effectiveness of transition: some indicative proposals

3.3.1 General approach

The EU energy systems face some new challenges such as, more active users at the center of the ESs, better engaging of users through better understanding of ESs, better information about energy market transformation, greater activating of users through innovative technologies, increasing energy efficiency in buildings, heating/cooling, and industry/services. The following actions are suggested by energy decision makers to deliver well these objectives:

- The best assess of macro-economic impacts of large-scale deployment of energy efficiency while taking into account its multiple benefits for end-users.
- To continue benchmarking analyses by compare user's consumption across neighbor cities and regions to increase end-users' engagement.
- To support, develop and evaluate innovative engagement actions to help users benefit from their new active role and change their behavior in everyday life.
- To setup an Energy Poverty Observatory to establish to monitor vulnerable users through adhoc indicators and transfer good practices from other regions. Yet, it will enhance public procurement and cooperative procurement techniques to help energy authorities make informed decisions and stimulate market transformation.
- To develop appropriate links between smart meters, in-home central energy management systems and smart appliances, including data-sharing platforms. Yet, to structure the unstructured of energy supply/consumption data and effective users' interfaces for smart meters, energy management systems while using relevant ICT solutions.
- To develop new energy business models concerning integrating supply/demand/flexibility and energy efficiency that be able to give a higher value to energy efficient and flexible behavior and will recognize the role of smart energy-related appliances and systems. These activities should enable players for easy market penetration of new energy services and innovative demand response solutions that are low cost and easy to be installed-plug/play.
- To develop new construct materials for new and existing buildings enabling the integration of multi-functionality, energy efficiency and on-site RES while taking into account their life cycle sustainability such as, cost-effective energy storage materials. Systems with intelligent control).
- To develop innovative building design tools taking into account pre-fabrication of components and enabling the advanced ICT systems, technologies, and solutions for building-to-building or building-to-grids interactions.

- To improve the viability and cost-effectiveness of mass manufactured, plug and play components/systems for deep building renovation, as well as, for innovative insulation solutions, control, automation, and monitoring tools, including innovation needed during the construction process.
- To develop intelligent models able to predict heating/cooling demand from all end-users.
- To develop smart solutions that will enable the effective combinations of centralized and decentralized power production using different energy sources. Yet, to develop and improve fluids that combine energy transfer function with thermal energy storage systems.
- To develop smart systems to increase the heat/cold storage density using phase change materials and thermochemical materials. To develop smart systems to increase the energy efficiency and reduce the cost of heat pump technologies, Combined Heat and Power (CHP) solutions along with energy storage systems.
- To develop the next generation of net-zero energy using apps, products, processes and systems. It means to develop new technologies for optimizing energy recovery in industrial processes such as, low temperature waste heat in industrial processes, new refrigerants, new smart CHP processes and distributed against centralized systems.
- To develop technologies for value-chain optimization through addressing energy efficiency
    - aspects in the know-how engineering phase of manufacturing equipment and processes, collective demand side strategies, and integration of the nearby RESs. Yet to ensure interoperability and connectivity of all smart technologies used in industry.
    - To develop, new grid and market planning methodologies, new grid topologies, new tools to improve asset management and the operation of distribution and transmission networks.
    - To develop tools for, optimizing further mature storage technologies, decreasing their **CAPEX/OPEX** costs , minimizing environmental impacts, maximizing their capacity, operability and life, operational benefits, and ease of use. This technologies include pumped hydro and cross sector technologies e.g. converting power to gas, fuel, chemical feedstock and heat and the possibilities for virtual energy storage.
    - To develop standards and smart interfaces to introduce storage technologies in the energy systems and explore synergies/complementarities with the grid and with demand side behavior.
    - To introduce smart devise solutions for increasing the flexibility of RES and Artificial Intelligence tools to simulate the contribution of flexible generation to the energy systems. At the same time will have to be developed virtual power plant approaches, such as those with small hydropower plants playing a major role in facing the peak demand moments.
    - To monitor and investigate the complementarities and benefits of flexible coordination among electricity, NG and heating systems, and develop big data analysis and cyber security solutions for all energy networks.

The scale of investment needed in the upgraded power sector and energy networks by 2030 has been estimated at more than € 23 billion, to 2040 € 28 billion, and more than € 35 billion to 2050. Part of these investments (45%) should be targeted at rolling to the market innovative generation assets and network infrastructures to ensure that the energy transition roadmap is based on increasingly competitive and performing technological solutions. Greek technology developers currently experience difficulties in raising finance for their first-of-a-kind commercial demonstration projects due to energy turmoil and Russian-Ukrainian crisis. The First-Of-A-Kind (FOAK) commercial demonstration projects in the field of power supply requires high volume of investment and should be considered as high-risk projects, which are difficult to be evaluated. Banks are more risk-averse under difficult market conditions like today times-covid and energy crisis. The tween crises make market conditions unstable, and tendencies differ between EU member. Yet, EU banks to ensure their bankability become more conservative, much more to FOAKs. FOAKs commercial demonstration projects call upon new business models that require an evolution of the power market framework, creating an important source of uncertainty.

Remarks:

1. Energy innovation projections for ease transition and their relations with EU guidelines.

Energy transition models in global literature show the interconnectivity of energy systems and relative innovations and smart technologies. EU needs global experience for faster transition to almost complete decarbonized energy system, reducing emissions by around 8% /year ensuring an energy future in line with the 1.5° C ambition, set under the Paris Agreement-2015. This urgent and complex challenges for ES need the closest cooperation among all countries worldwide and complete understanding the timeline and interdependencies of technologies and energy policies. It also needs great courage to be made difficult decisions. To this context, globally innovations will be focused to those sectors with greater performance, profitability, and impact on cost-effective transition. IRENA suggests two adhoc criteria for how to choose a country or organization an energy technology to achieve the best result of transition. **First** is the measure of how quickly the technology is being deployed and whether costs are expected to fall over the next ten years. Many of the technologies have already seen big reductions in cost and will double in capacity many times over the coming decades till 2050. **Second** is how well such technologies interact each other, sometimes referred to as sector coupling or energy production value-chain integration. The overlapping and supplementary nature of some technologies can combine to create a step change and accelerate the creative destruction of existing low performance technologies and pave way for the entrance of some new one. Within this global context, European Strategic Energy Technology Plan (ESET-Plan) can be considered as pillar of research and innovation in EU energy and climate policy. The EU adopted from global experience and suggests the next technological priorities grouped by key objective of the Energy Union: [11], [19], [20]:

- Taking the first place in the world in RES power share in energy mix-more than 85%. -Providing a smart client-centered energy system.
- Strengthening of energy efficient systems- performance focusing.
- Differentiating and strengthening of energy options for sustainable transport.
- Guidance of ambition in carbon capture, use and storage, decarbonization focusing.
- Increase safety in the use of nuclear energy, high-safety in nuclear power plants. All EU member states will have to specify the Energy Specialization Strategy-ESS in national/regional level boosting the energy transition.
- Boosting R&D activities of SME's in the energy sector to promote innovation and business networking.
- Promoting the partnership of companies in the energy sector with research organizations where the cooperation in R&D projects is promoted.

- Utilizing of research results in the field of energy transition that have been produced by previous research projects.
- Creating innovative clusters of companies in the context of the "National Energy Strategy of Intelligent Specialization and Specialized Energy Networks Centers" that aim at strengthening integrated programs for the creation and support of innovative collaborative clusters
- Creating a Business Participation Fund (Equifund) which will be an investment platform with a multiplier impact on the economy, energy and society, helping to be found financing by venture companies.
- Utilizing of the research / innovation result for energy, produced by research bodies and aims at the financing of partnership schemes, universities, research bodies, etc. -Strengthening of startups, Spin-offs/outs of energy sector for the commercialization of mature research results innovative ideas and patents.
- Participating in energy programs funded under "**Horizon 2020**" and systematically promotes research and innovation aiming at smart, sustainable and integrated development, as well as the effective response to various important social challenges.

2. World Economic Forum 2021: trends that we should expect to energy industry:

- **Dramatical switching to high efficiency RES for power production:** With the aim of limiting the rise in global temperature not more than 1,5 ºC, the RES penetration will cover an 85-95% of power generation. The innovation lies in the doubling of their efficiency till 2050, from 20-50% to 40-98%. Solar and wind energy are the most efficient and cost-effective among all types of RES with the above evolving technologies, so we can expect to see RES to be the most preferred.
- **Innovative energy storage facilities:** The best balance of the power supply and demand needs a cost-effective amount of energy to be stored and this is the key to tackling the intermittent issues of RES. Today batteries are a good option to store energy, but still, on account of their expensive nature, it is expected an improvement in other energy storage technologies that can not only make them viable but also affordable at once. Pumped-hydro large scale effective systems, green and blue hydrogen, oceanic/sea waves, photosynthesis are the key-expected innovations.
- **Very smart Macro/Micro/grids based on AI/ML:** The grids will operate both, as power transmission lines and as energy manager savers, offering entire intelligence services to energy systems backing by Artificial Intelligence and Machine Learning tools.
- **Blockchain and Internet of Thinks as smart energy systems toolkits:** Blockchain and IoT support an energy system in the same way, as they do in other industries. They work as distributed ledgers that record all the transactions through a peer-to-peer network incorruptible. Introducing and using blockchain in energy system we can eliminate the need for every moment human presence in energy supplying. This will solve the issues of inefficient and unequal energy distribution and empower the end-users to trade energy directly.
- **Grid parity with diminishing costs:** The new energy sources have the potential to generate power at the less cost and higher efficiency than traditional ones. This grid parity occurs with the help of sun and wind.
- **Enhanced electricity management:** It means the best matching between energy supply and demand, since electricity has to be consumed in production time and not to be stored. This implies that the demand for energy will never decrease, in contrary, it will definitely rise with the enhanced standard of living. Thus, looking at this situation, it is necessary for the energy policy makers, manufacturers, and energy producers/distributors to come together to set some new managerial standards that can aid in enhanced energy management. These new managerial techniques are contributing significantly to strengthening grid reliability and flexibility.
- **Replacing the nuclear fusion power plants by nuclear fission ones:** This will require substantial continued innovation in existing technologies, but it is impossible without the deployment of break-throughs till 2040.

3.3.2 Innovative measures boosting energy technologies facilitating the Greek transition process

The energy landscape according to IEA will change more in the next 10-15 years than in the previous centuries. As the world's energy sector moves away from fossil fuels toward RES, energy-intensive companies are challenged with addressing this transition in transformative ways. Digitization will be the key to making power-generating assets more efficient, the electric grid more secure and resilient, the transportation/aviation industry more sustainable and innovative, helping manufacturers reduce whatever waste. Decarbonization requires balance between legacy systems and emerging energy technologies and between the environment and business economies. As the manufacturing industry converts to cleaner energy and variable RES-wind and solar become more available, utilities must balance the power mix to ensure electricity will be available when and where it's needed. Yet, the global power demand is estimated to grow by 50%-60% by 2050, which means it's imperative that energy is affordable, even in a more complex and dynamic environment. To this frame we consider useful to give some indicative and innovative investment opportunities associated with energy transition.

3.4. Estimation of additional costs caused by risks related to large scale necessary investments for energy transition

General principle, better access to low-cost capital is critical to improve the affordability of energy transition. Putting the global societies on a path to achieve almost zero emissions till 2050, requires an increase of capital-intensive clean energy investments. Investments in wind, solar PV, electric vehicles, and hydrogen electrolysers technologies, which have somewhat relatively high upfront investment costs (CAPEX) and lower operating and fuel expenditures over time (OPEX). But the economy-wide cost of capital remains rather different between national economies. Looking at the value of state base rates, plus a broad market risk premium, nominal financing costs can be up to 700% higher in emerging and developing economies compared with those such as USA and EU(IMF 2021). Spatial -related risks and not well-developed local financial systems account for much of this difference, which can be even greater in riskier energy markets. Different energy industries will have different capital structures, making them more sensitive to variation in the CAPEX and OPEX. Often, investments in power systems rely on high levels of debt, which, in turns, reflects the fixed element in cost and revenue structures. IEA World Energy Model incorporates differentiated cost of capital assumptions, taking into account certain indicators, as well as additional assessments of risk premiums across regions and sectors. To the next we present some data which used to so-called business models and indicative WACCs of utility-scale RES projects, estimating the systemic risk in EU basis and Greece in average terms (2019).

Table 8. Indicative investment opportunities in power innovations

Greece *	REMTH*	Investors with interest in investments
Creation of new smart infrastructures for NG, transmission, liquefied	Creation of new smart infrastructures for NG, transmission, liquefied	Third Point Gas-USA

Greece *	REMTH*	Investors with interest in investments
terminals, pipelines, and distribution systems	terminals, pipelines, and distribution systems	
New technology and high performance RES projects-Wind, P/V, biomass, geothermal, etc	New technology and high performance RES projects-Wind, P/V, biomass, geothermal, etc	Shenhua-China, China State Grid, Fairfax Holdings-Canada
Smart and high performance power storage systems	Smart and high performance power storage systems	Shenhua-China, China State Grid, Fairfax Holdings-Canada
Investments in smarter ES and greater energy performance and energy saving	Investments in smarter ES and greater energy performance and energy saving	SENFLUGA Energy Infrastructure Holdings S.A -Spain
Smart interconnection of electricity transmission system with 16 islands and the upgrade/expansion of the cross-border electrical interconnections-Egypt, Israel, Cyprus, Libya	Smart interconnection of electricity transmission system with 2 islands and the upgrade/expansion of the cross-border electrical interconnections-Maritsa East, Eurasia, IGB	SENFLUGA Energy Infrastructure Holdings S.A -Spain, Shenhua-China, China State Grid, York Capital Management-USA
International public tenders for the exploration of hydrocarbons	----	Fairfax Holdings-Canada, York Capital Management-USA
Investments in production of smart equipment and components for RES	Investments in production of smart equipment and components for RES	Shenhua-China, China State Grid
Floating wind turbines- Aegıan sea	Floating wind turbines-Thracian sea	Shenhua-China, China State Grid, Fairfax Holdings-Canada
P/V system technologies: new inverters, trackers, and racking solutions for whole PV systems are increasing system performance and yield further reducing costs	P/V system technologies: new inverters, trackers, and racking solutions for wholePV systems are increasing system performance and yield further reducing costs	Shenhua-China, China State Grid, Fairfax Holdings-Canada
Waste-to-energy production: Energy recovery from biogenic waste in the form of electricity and heat is on the rise worldwide, driven both by the increased availability of waste and by technological developments	Waste-to-energy production: Energy recovery from biogenic waste in the form of electricity and heat is on the rise worldwide, driven both by the increased availability of waste and by technological developments	Many Greek, EU and other investors
Mechanical recycling: solutions exist to prevent polymer chain scission during extrusion including antioxidants and chain extenders, but there is a lack of standards and know-how as to the effect of these processes on the quality and safety of recycles	Mechanical recycling: solutions exist to prevent polymer chain scission during extrusion including antioxidants and chain extenders, but there is a lack of standards and know-how as to the effect of these processes on the quality and safety of recycles	Many Greek, EU and other investors
Pipelines for low-carbon gases/H2 green: such pipelines will play a critical role in transferring new low GHG gases, but safe transferring and high financial risks will have to be taken into account. Many design, construction, and operational considerations go into developing future low-carbon gas pipelines.	Pipelines for low-carbon gases/H2 green: such pipelines will play a critical role in transferring new low GHG gases, but safe transferring and high financial risks will have to be taken into account. Many design, construction, and operational considerations go into developing future low-carbon gas pipelines.	Many Greek, EU and other investors
Nanomaterials for sustainable buildings: develop and production of super-hydrophobic coatings that could be applied to existing buildings would be of huge benefit to the industry	Nanomaterials for sustainable buildings: develop and production of super-hydrophobic coatings that could be applied to existing buildings would be of huge benefit to the industry	Many Greek, EU and other investors

Source : RAE-IENE reports 2019,2020,2021, IRENA report 2021 and WEF report 2022

*** These projects are very importance, with significant added value: production of equipment and components for RES 75%, assembly of W/T 35-50%, assembly of P/V systems 35-65%. Such investments in innovative products/services will enable Greece/REMTH to operate as an exporter of clean energy systems, in addition to strengthening its energy autonomy**

Table 9. Indicative indicators estimating the systemic risk in EU basis and Greece in average terms (2019).

Indicative indicators-PPA*	**Revenues supported -Feed-in tariff, contract for difference, long-term PPA**	**Merchant risk Market-based revenue**
Revenue risk: price	Low	High
Revenue risk: volume	Low	Medium
Revenue risk: Off-taker	Low	Medium
Debt base rate after tax (%)	0,3-0,4	0,3
Debt Risk premium after tax (%)	1,9-2,0	1,9
Cost of equity (%)	5,3-11,1	0,9 – 14,5
Share of project debt (%)	75,0-85,0	40,0 – 50,0
Debt base rate after tax (%)	2,6-4,3	6,5 – 9,6
WACC real, pre tax (%)	2,4-4,0	5,9 – 8,8
*PPA = power purchase agreement.		

Source: IEA (2020), World Energy Outlook 2020 /www.iea.org/articles/the-cost-of-capital/

Financing energy transition in energy-intensive manufacturing firms will require investments in new RES technologies and attracting capital at scale in cement, chemicals, and metallurgy. Many of the RES technologies needed to meet the long-term almost zero emissions goals at early stages of market readiness, attracting project finance from banks. In IEA climate-driven scenarios, emissions reduction initiatives over the next three decades focus on improving the efficiency of industrial equipment and fuel switching, mainly to electricity and bioenergy but also to NG/LNG in fields where cleaner energy cannot yet be deployed on the scale needed. Yet, transitions need to focus on laying the groundwork for a rapid scale-up of low-carbon technologies for producing hydrogen and CO2 capture.

Regarding the use of other mathematical models to estimate the systemic risk concerning the energy transition we can refer to two types of them, the projects risk models, and the valuation models. The **first,** testing the potential economic risks of a large-scale project in terms of cash flows, net margin impact and capital expenditure changes. The **second,** designed to assess the value of financial assets which can be applied under different energy transition assumptions. Literature suggests that cash flow-based approaches are among the most common globally. Risk exists to any large scale project since it is designed and implemented within unpredictable conditions and uncertainty. These mean that we ever have to estimate the uncertainty with the greater probability. The next table gives the risk of energy transition to large scale project of energy transition based on a project risk model (IEA 2021).

Table 10. Risks related to different types of power generation after energy transition-qualitative basis.

Type of technology	**Risk on health**	**Noises**	**Risk on infrastructure**	**Risk on natural environment**	**Worst risk scenario**
Lignite /coal-no interest for REMTH	Min due to modern emission reduction filters and process optimization. Severe if such technologies are not applied	Depending on emissions	Sever to moderate	Depending on emissions for plants	Local effects on air, lang cancer
Natural gas	Min to moderate	Min	Minor owing to pipelines	Minor to moderate	Local effects on air
Hydro-power	Zero	Mid in case of dams, min for pumped - storage	Mid locally for transport and communication	Mid in broader area	Local damages due to floods
Solar systems	Zero	Zero	Zero	Problems due to PV recycling	None
Wind systems	Zero	Noise, vibration	Affect propagation	Avians, birds collision risks	None
Biomass	Moderate	None	Min	Significant	Local
Geothermal	None	None	None	None	None

Source: Bielecki at al. (2020). "The externalities of energy production in the context of development of clean energy generation", Environmental Science and Pollution Research-Springer.

Since, a part of risk is the new immature technology used in power production, it is in force the principle "the more mature energy technology, the smaller risks". Next τable presents the risk correlated to energy technologies used in power production.

Table 11. Features of the main energy-generation technologies: correlation among tech and risk.

Type of technology	**Fix /variable production**	**Type of fuel**	**Flexibility in production**	**Low carbon**	**CO2 emissions as Kgr/KWh**	**Correlation**
Lignite /coal	Fix	Fossil	Medium	No	952	15≤
Natural gas	Fix	Fossil	High	No	458	10≤
Hydro-power	fix	RES	Very high	Yes	≈0	20≥25
Solar systems	Variable	RES	Very low	Yes	≈0	16≥25
Wind systems	Variable	RES	Very low	Yes	≈0	16≥30
Biomass	Fix	RES	High	Yes	≈0	10≥15
Geothermal	fix	RES	Medium	Yes	≈0	20≥25

Source: Bielecki at al.(2020) “The externalities of energy production in the context of development of clean energy generation”, Environmental Science and Pollution Research-Springer

3.5. Costs out of energy systems

3.5.1 Estimation of power production changes and external costs in REMTH due to transition.

The external costs caused by the environmental impact of power production are significant in most EU countries- therefore in Greece/REMTH- and reflect the dominance of fossil fuels in the power mix. In 2019 the average external costs of electricity production in the EU-27 were between 1.8–6.0 Euros/MWh. Despite the progress in clean energy technologies, external costs are still not adequately reflected in energy prices, because the energy cost for end-users will be increased by 30-35% (IEA 2020). Therefore, end-users, power-producers and decision makers do not enjoy the accurate price signals that are necessary to reach decisions about how best to use resources. Power production causes serious environmental and human health damages, which vary widely, depending on how and where the power is produced. The more trusty estimation of the external costs needs smart economic tools like Social Cost Benefit Analysis combining with other by case, so that to be imprinted all the factors involved in the issue. When SCBA is combined with information on environmental taxes and economic instruments, then adhoc indicator can be formed giving more clear picture about the external cost of power production, transmission, and contribution. The key-principles of environmental economy related to external costs and will have to take in account by estimation models are [11], [12], [13]:

- The **property rights**: The absence of concrete property rights in many environmental resources encourages their violation.
- The **external cost**: It is the “hidden” cost that is not recorded by the market mechanisms, but it causes damages to whole environment.
- The **polluters have to pay their pollution**: The responsible power producers must pay the corresponding expenses for the damages they cause to environment and its restoration.
- The **determination of the least level of pollution by power source**: Pollution must be reduced to that point where the cost of reducing it equates to the environmental benefit.
- The **method used for measuring environmental cost with greater accuracy:** This cost has to be taken in account when we cost the power produced by a natural source.
- The **social benefit assessment of power generation**: It will have to be made with SCBA method and will have to include impacts on employment increasing, security of energy supply, RES penetration % and the improvement quality of urban landscapes, creating green spaces and recreation.

To the table below, externalities are formed to categories, according to global literature:

Table 12. Externalities formed to categories can carry out to REMTH.

Basis of externality	**Impacts**	**Description of impact**
Prosperity	1.Positive externality	It is caused increased of prosperity
	2.Negative externality	It is caused decreased of prosperity
Type of good	1.Environmental externality	The change in prosperity is related with changes in the state of environmental goods
	2.non-environmental externality	The change in prosperity is related to changes in other aspects of social and economic life
Potentiality for cost transfer	1.Monetary external economy	Externalities are expressed directly in monetary units
	2.Technological external economy	Externalities are expressed directly in qualitative basis
Change of prosperity in relation to change production volume of a good	1.Constant externalities	Externalities do not change as the production volume of a good is changed
	2.Variable externalities	Externalities change as the production volume of a good is changed

Source : Burtraw D and Krupnick A [2012]¨”The true cost of electricity production” Center for Energy Economics and Policy, Resources for the Future -adaptation and compilation by author

The figure 10 below gives, in very illustrative way, the pollution process by polluter in spatial basis, and it can be carried out to our case of REMTH.

3.5.2. Estimating the external cost and uncertainties of energy transition

Global literature refers to both, SCBA as a general approach to estimate costs/benefits of power production systems and Life Cycle Assessment Analysis (LCAA) as an adhoc approach for estimation only the negative impacts of power production systems, or as a technoeconomic analysis for assessing potential environmental impacts associated with a power production systems.

According to the ISO 14040 and 14044 standards, SCBA and LCAA in order to be used as estimation processes of large energy projects will have to be carried out the steps:

1. To put the goals in very clear way.
2. SCBA has to take in account the most possible factors implicated.
3. LCAA has to take in account the most possible factors implicated which will be evaluated so that to be able measured all the potential environmental impacts associated with energy inputs and outputs
4. The best interpretation of the results in relation to the goals of the study.

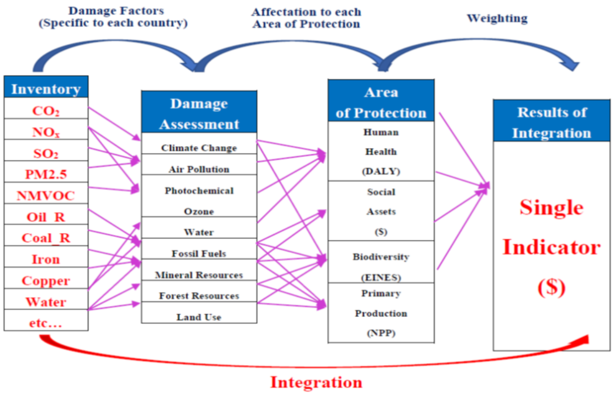


Fig. 10. pollution process by polluter in spatial basis (source: Barreca, A, et al. "Adapting to Climate Change: The Remarkable Decline in the US Temperature-Mortality Relationship over the 20th Century." Journal of Political Economy 124(1), 2016, 105-159.

The negative impacts caused by electricity generation from 486 MW power plant located in REMTH/Komotini, using NG as fuel, are serious, although less comparing to those of coal/lignite. The impacts refer to atmospheric pollution impacts on: human health, workers, materials, crops, forests, freshwater, and fisheries, or on well-being of local society as a whole. The previous mean environmental damages, causing direct/indirect economic costs, which are usually not reflected in the price of electricity production/supply. Till now, these hidden costs are ignored in energy decision making and planning. Yet, such phenomena/externalities are plausible to arise uncertainties in several ways, including: variability inherent in any set of data, extrapolation of data from the labs to the field and exposure-response data from one region to another, difficult assumptions regarding threshold conditions, lack of good information with respect to human behaviours, political and ethical issues-the selection of discount rate and the need to assume some scenarios of the future for any long term impacts, etc. Externalities are hidden costs of energy activities that are not directly linked with these activities. So, the definition that the total energy cost includes both, the private one that directly related to the energy activities and the external one, indirectly related to society such as the impacts of GHG emissions on health, ecosystems, agriculture, climate, and buildings.

Further, externality theory in energy economics is related to both, negative (fossil fuels) and positive(RES) production externalities. Negative production externality exists when a power production unit reduces the well-being of people who live near the unit and are not compensated by the power producer. In order to estimate in a region such as REMTH, the negative power production externalities we need the follow information:

- Positive/Negative Production Externalities (PPE/NPE): it depends on type of energy.
- Private Marginal Cost of certain power producer(PMC): is the unique direct cost of power producer when he adds an additional power quantity (MWh).
- Marginal Damage (MD): is any additional costs associated with the power production imposed on other stakeholders but that producers do not pay.
- Social Marginal Cost/Benefit (SMC-SMB): is the private marginal cost of power producers plus their marginal damage(SMC = PMC + MD). In liberalized energy markets, quantity and price are linked by the equation PMB = PMC and SMB = SMC. Coase R formed the question whether externalities really lie outside the energy market mechanisms. The R-Coase Theorem offers a potentially useful way to think about how to best resolve conflicts between competing businesses or other economic uses of limited resources. [62], [63], [64], [65].

The graph below (Fig. 9) depicts the distinctions between unique power price and its quantity solving the externalities problem based on Coase R Model.

The data taken in account to estimate the today externalities of REMTHs ES in its environment from its power production system are the follow:

- **NG power plant of Komotini**: Power nameplate 484,6 MW, actual power 476,3 MW, CF=38,6, annual operation 5.500 hours, power production 1.400 GWh, emission of 364 Kgr GHG/ MWh, total external levelized cost=6,9€/MWh, distributed in: human health deterioration 1,1 € (mortality = 0,7€ and morbidity=0,4€), agricultural products deterioration 0,15€, and clear environmental 5,65€.
- **Hydropower plant of Nestos**: Power nameplate 480 MW, actual power 478 MW, CF=48,4, annual operation 7.200 hours, power production 920 GWh, emission of 24 Kgr GHG/ MWh, total external levelized cost=2,5€/MWh distributed in: human health deterioration 0,0 € (mortality=0,0 € and morbidity=0,0€), agriculture 0,1€, and environmental 2,04€. –
- **Wind parks**: Power nameplate 501 MW, actual power 325 MW, power production 1.956 GWh, emission of 16 Kgr GHG/ MWh, total external levelized cost=2,5€/MWh distributed in: human health deterioration 0,0 € (mortality=0,0€ and morbidity=0,0€), agriculture 0,1€, and environmental 2,04 €.
- **Solar and P/V systems**: Power nameplate 485 MW, actual power 418 MW, power production 720 GWh, emission of 6 Kgr GHG/ MWh, total external levelized

cost=2,5€/MWh distributed in: human health deterioration 0,0 €.

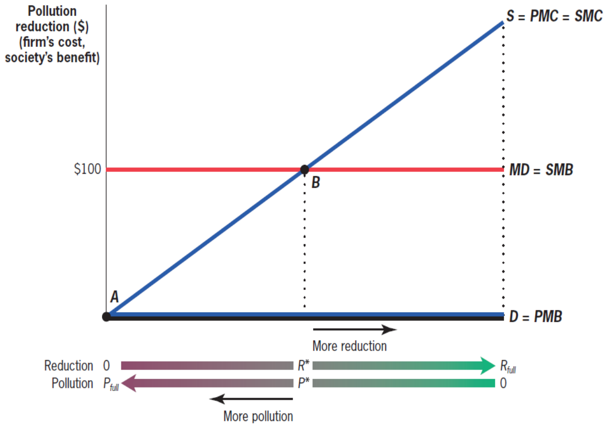


Fig. 11. Distinctions between power price and quantity approaches to addressing externalities of Komotini NG power plant 486 MW (Source: Jonathan Gruber Fourth Edition Copyright © 2012)

Having the data, we can estimate the today negative impacts in REMTH if the transition roadmap stops-somewhat it is a social opportunity cost. From the data getting by official sources we result that the MD in REMTH is € 2,4 million for every additional 10 MW power in NG thermal plant- the RESs power remain constant. If we assume two scenarios for NG thermal plant, one with the max MD € 4,5 million for every additional 10 MW, presented as maMD and one with the min MD € 2 million for every additional 10 MW, presented as miMD, then for the annual power production of REMTH being today equals to Q=2.950.000 MWhs we can tell:

- $CmaMD(Q) = 4{,}5\,Q^2 = MCmaMD(Q) = 9Q \qquad (1)$
-
- $CmiMD(Q) = 1{,}0\,Q^2 = MCmiMD(Q) = 4{,}5Q \qquad (2)$
-
- ETC cost is included
-
- $Q(maMD) = Q(miMD) = 0 \qquad (3)$
-
- no ETC taxes, or other environmental regulations.

The decreased environmental damages and social welfare maximization due to less pollution because of the power producing is improved via transition process reach the 50% of initial pollution existed to today ES structure and it can be calculated by the equations 1,2, 3 and can take the formulas:

$$V = \max Q^{maMD} + Q^{miMD} - Q^{miMD} \cdot Cmin\,(Q^{maMD}) - Cmax(\,Q^{miMD}) = Q^{maMD} \cdot Q^{miMD}$$

$$MCmaMD = 3 \rightarrow MCmiMD = 1 \rightarrow Q^{maMD} = \frac{1}{9} \rightarrow Q^{miMD} = 0{,}89 \ or \ 89\% \qquad (4)$$

Optimum outcome for REMTH is to have the lower cost power production along with the min pollution, or the greatest GHG reduction per MWh produced by the NG power plant. Final outcomes of Q^{maMD}, Q^{miMD} do not depend on initial regulation of Q^{miMD}, Q^{miMD} being 492 kgr GHG/MWh. When the quantity regulation calculated with the tradable CO2 taxes-about €122/MWh (12/2021), then the price of MWh remains efficiently competitive as long as the total **Q-**quantity also remains the same and then equation takes the form:

$$-Q^{maMD} + Q^{miMD} = 1 \qquad (5)$$

Remarks:

- The levelized external cost values per kgr of pollutant provide useful information on the cost of impacts caused by each category of pollutant, regardless of the type of power plant, fuel used and the amount of emissions.
- In the analysis of external costs, the factors that differentiate the results are, the geographical location of each power plant and the estimated impact of each pollutant, regardless of the type of fuel. It turns out that, for all **ExternE versions**, the distribution of external costs in impact categories is about the same on average terms.
- A central methodological aspect of the ExternE program is that the analysis should not be limited to the stage of electricity generation, but instead, it extends to all stages of the production process, from the mining and transfer of natural resources and fuels to the final stage of disposal and storage of waste. An approach based on **Life Cycle Analysis-LCA**, is therefore required. LCA is successfully applied for the comparison of environmental loads coming from different production sources, but it is not sufficient to assess the impacts, as the geographical location of the energy sources

Finally, based on the above 5 equations and the available 20 years data for energy of REMTH in timeseries form, and further elaborated through descriptive statistics result the following outcomes collected in table 13.

Table 13. Summary of descriptive statistics for negative externalities associated with power production/supply-2020.

Statistical measure /power technology (2000-2019)	Natural Gas	Hydro power	Wind parks	Solar systems	Biomass
Min	-0,004	0,0003	0,0	0,0	-0,0
Max	12,97	64,12	0,82	1,79	21,89
Average	5,13	8,45	0,32	0,67	5,34
Median	3,78	1,14	0,31	0,62	2,76
Standard Deviation	4,69	17,98	0,23	0,56	6,10
Number of observations	240	240	240	240	240

Some negative externalities have more serious impacts on REMTHs social and economic environment and therefore it is considered necessary to be presented in form of "past failures, damages and effects". Their accurate assessment today and after the transition is the demanded answer-noting that some types of damages/failures cannot be complete quantified.

Table 14. External casts and risks.

Failures /damages/effects	**The former 20 years**	**After transition**
Accidents affecting workers as % total operation time	3,2	0,9
Atmospheric pollution on unmanaged ecosystems as %	15,0	2,0
Atmospheric pollution on human health as %	2,5	0,5
Atmospheric pollution on materials as %	2,0	0,4
Atmospheric pollution on crops as %	5,0	0,5
Atmospheric pollution on forests as %	15,0	0,2

Atmospheric pollution on freshwater fisheries as %	12,0	0.4
Effect on atmosphere warming in Celsius degrees	+0,2	-1,5
Impacts of noise as %	3,2	1,5

Source : WHO adhoc reports 2001-2021: adaptations and compilation by author

3.6. Conclusions

We have seen that the external costs of the current REMTH's ES structure is quite high ranging from € 2,5 to € 4,5 per MWh. The main source of high external costs is the NG thermal plant with nameplate power 486 MW, locating in Komotini. So, when it will close by 2040, the above external costs will be reduced dramatically by 89%, with a corresponding improvement of all indicators of so-called well-being.

4. SUB-PART B: The Profile of Greek/REMTH'S Energy Systems.

4.1.Describing the today Greek and REMTH's energy/electric systems

Lignite was the key-domestic fossil fuel for electricity production, contributing to power mix and balance between 75% till 2008, 35% till 2018 and only 9% in December 2021. The two ES's are distinguished in the National Interconnected System (NIES) and the Islands System(IES), and are consisted of by three power subsystems, production, transmission, and distribution. Essential role of them is to produce, supply, transmit power to every end-user in the best lower price with the least possible ecological impact, ensuring constant voltage/frequency and high supply reliability. The basic structures of Greek/ REMTH's ES's are:

- **Production/generation system**: Includes thermal and RES power units 21.450 MW(2021).
- **Macro-grids transmission System-TS**: The national interconnected transmission system consists of by transmission lines of high (150kV) and hyper-high (400 KV) voltage) and decreasing voltage transformers for hyper-high and high voltage power transmission.
- **Micro-grids transition system**: Transfers power in smaller power with lower voltage from transmission substations to distribution substations of smaller consumption centers. It is noted that large industrial consumers are usually fed directly from the sub-transmission system.
- **Distribution system**: Includes the MV and LV power distribution networks, to which the substations also belong.
- **Power Compensation Condensers - PCC**: The needs for reactive power compensation are met/balanced by installing stator capacitors and compensator coils.
- **International interconnections**: Greek ES operates simultaneously and in parallel with the interconnected European Systems under the general coordination of ENTSO-E (European Network of Transmission System Operators for Electricity). Its parallel operation with the European ones is achieved through interconnection lines mainly 400 KV (ES of Albania, Bulgaria, N. Macedonia, and Italia through subsea cable).
- **Marginal Price of the System-MPS**: It is the hourly price at which the electricity market is cleared. That is, the price enjoyed by power producers/suppliers injecting power into ES and paid for this. MPS is the largest part of competitive electricity costs since, it is formed by the combination of the offered prices and quantities in hourly basis, submitted every day by the power producers. In tabular form the Greek/REMTH ES's have the below technoeconomic features.
- **Formation of the final price KWh:** The price of KWh depends on a number of different supply and demand conditions. The most important of these are: the global geopolitical situation, the national energy mix, the cost of transmission and distribution networks, the cost of environmental protection, discounts of poor customers, energy import factors, weather conditions and taxation level.

Table 15. The main features/structure of Greek and REMTH's Electrical Systems (ES, 2020).

Features of Greek electric system	Greece	REMTH
Extension in KM2	132.230	14.157
Population	10.870.000	608.720
Total power (MW)	20.313	2.381
Number of clients/consumers	7.563.000	487.500
Total electricity production(TWh)	4,63	0,69
Total electricity demand/consumption(TWh)	5,43	0,48
Total imported power(TWh)	0,8	--
Annual peak demand (GW)	10,3	0,60
Total RES power (MW)	5.897	1.430
Total production of RES (TWh)	1,25	0,31
Average marginal cost of total power system €/MWh	1.287	1.076
Average marginal cost of thermal power system €/MWh	485	345
Average marginal cost of wind power system €/MWh	198	203
Average marginal cost of P/V power system €/MWh	183	197
LCOE of ES at 31-12-2021- €/MWh	8,6	7,5
Average consumption per client (KWh) (included all end-users)	6.173	5.968
Energy tension- toe/ unit of GDP, or toe/million €	173	158
CO2 emission tension, measured as CO2 tons /toe	3,1	0,08
Energy dependence, measured as energy imported/ total energy consumption %	65,0	-------
Total energy consumption per capita, measured as toe/capita	2,8	2,6
Total electricity consumption in KWh/capita	5.361	4.788
Total electricity production per capita measured as KWh/capita	4.592	

Energy consumption elasticity: $Y = 0{,}967 + 1{,}8617$ and $R^2 = 6{,}429 \rightarrow$ it means an 1% increase of GDP bears a 0,967% increase of energy consumption	4,9	5,2
Total consumption TWh	51,2	2,4
Domestic use in TWh	17,5	0,8
Commercial use TWh	14,4	0,6
Industrial use in TWh	13,8	0,7
Agriculture use in TWh	2,7	0,2
Use by public entities in TWh	2,0	0,1
Wind MW / inhabitant	0,086	0,78
Average wind speed m/sec	8,6	8,8
Wind power in MW	2.310	237,1
PV- MW / inhabitant	0,058	0,104
Shiny $\frac{\frac{\mathrm{kwh}}{\mathrm{m}^2}}{\mathrm{year}}$	1.284,8	1.258,8
Surfaces of P/V panels (M^2)	0,921	0,876
REMTH is still entitled new MW of RES by 2050	18.800	2.500
Transmission grid in km 400 KV arial and underground km	2.632	143
DC Transmission grid in km 400 KV arial and underground km	267	11
Transmission grid in km 150 KV arial, subwater and underground km	8.350	234
Transmission grid in km 66 KV arial, subwater and underground km	55	4
Current transformation sub-stations	291	13
Installed power in MVA	50.750	1.475
Ranked among EU-28 ES's based on cost competitiveness and supply/transmission reliability	12	11

Source : RAE reports 2019-2020

Table 16. Voicing methods per category of energy users

Clients	**€/MW**
High Voltage	
Voicing yearly	24.062
Mean Voltage	
Permanent fix voicing per MWh	1.197
Variable voicing per MWh	0,28
Low Voltage	
\Agreed power per year 0,13€/KVA	0,542
Beneficiaries of household low voicing	0,602
Adhoc tax for SHG emissions €/MWh	
Low Voltage homework	17,0
Other Low Voltage	17,0
Businesses with activities of Annex 3 of the Guidelines with EHE <10%	2,55
Businesses with activities of Annex 5 of the Guidelines with WEE ≥ 10% and WEE <20%	3,4
Businesses with activities not included in Annexes 3 /5 of the Guidelines with WEE ≥ 20%	3,4
Lignite mines and pumping stations with connection to the high voltage, and fixed orbit means with connection to the medium or high voltage	3,4
Agricultural use low and mean voltage	9,01
Common Benefits Services CBS €/MWh	
High Voltage	4,14
Industrial Use Mean Voltage >13 GWh	4,14
Industrial Use Mean Voltage	6,91
Agricultural use low and mean voltage	7,07
For General use Mean Voltage	17,9
Squares/streets lighting	13,71
General use low Voltage	18,24
Industrial Use low Voltage	18,24
Home use 1-1600 KWh/4 months	6,9
Home use 1601-2000 KWh/4 months	50,0
Home use >2000 KWh/4 months	85,0
Night invoiced clients	
1-1600 KWh/4 months	6,9
1601-2000 KWh/4 months	15,0
>2000 KWh/4 months	30,0

Source: https://ypen.gov.gr/energeia/ilektriki-energeia/lianiki-agora/timologisi-ilektrikis-energeias/

4.2. Technoeconomic specialties of Greece /REMTH's energy electricity systems

In this part we will analyze three key-issues, how could be used and delivered far more efficiently the today energy produced, how should be expanded a more clean, reliable, affordable and sustainable energy mix and, how could create innovations in energy technologies, regulations and policies than those already existed.

- **Reliability REL**: is the ability of the ES to perform its mission adequately for the planned time period and prevailing operating conditions.
- **Adequacy of Operation=AO:** is related to the existence of facilities capable of meeting the demand of the load taking into account the operational constraints of the ES, such as the power in MW of reserve plants required to be available.
- **Operating Safety-OS**: is related to the ability of the ES to respond to dynamic disturbances that occur, local or more distant, and include the sudden loss of a significant amount of power generated, transmitted, and distributed. Eg, problems that could lead the ES to dynamic, transient or instability voltage.
- **Levelized Cost of Electricity LCOE:** it estimates, track and compare the financial cost competitiveness of different power generation technologies, taking into account the full project life-cycle from development to financing to construction and then operation. LCOE allows to capture the impact of the timing of cash flows, development and CAPEX/OPEX costs, multiple stages of financing, interest and tax implications of long-term debt instruments and depreciation, among other drivers.
- **Loss Of Energy Expectation, LOEE = MWh / year:** is the expected energy which will not be produced by the generation system due to those circumstances in which the load demand of the system will exceed the corresponding available power. It is the ideal indicator to better represent the production system.
- **Loss Of Load Expectation, LOLE = hours / year:** is the average number of hours in a specific analysis time period, for which the hourly peak load exceeds the total available system power.
- **Frequency of Loss Of Load, FLOL = events / year:** it refers to events that the ES load demand is greater than the corresponding available power.
- **Expected Demand Not Supplied, EDNS = MW:** it is given by the LOEE / LOLE relation.
- **Average Duration of Loss of Load, ADLL = hours:** it is given by the relationship: LOEE / FLOL.
- **Energy Index of Reliability, EIR = € / MWh power does not be provided:** it is used to compare the operational adequacy of ES of Greece / REMTH which present differences, mainly in terms of their size. The next table gives a picture about the ES's of Greece/REMTH for four certain periods, power produced, low and high voltage, power losses, peak and least demand, power production mix, in order we can shape clear view regarding the past developments that should consist of driver for the future.

Table 17. Power produced, low and high voltage, losses, peak and least demand, power mix 2004, 2017, 2018 and 2019.

Developments of energy systems/Year	**2004**	**2017**	**2018**	**2019**
Outline of electric system -ES				
Total electric load distributed MWh	57.965	47.202	46.729	47.275
To low and middle voltage clients %	79,54	80,10	79,63	79,94
To high voltage clients %	14,29	15,36	15,72	15,24
Losses of electric system %	2,55	2,37	2,64	2,52
Lignite mines %	1,96	1,39	1,36	1,40
Pumped hydro %	1,48	0,23	0,05	0,12
Own consumption %	0,17	0,56	0,59	0,52
Total %	100,00	100,00	100,00	100,00
Peak demand load MW	10.417	9.368	8.493	11.162
Minimum demand load MW	2.456	2.315	1.818	2.628
Special indices				
Reliability REL	83,2	81,4	82.2	82.9
Adequacy of Operation=AO	92,5	94,3	94,6	95,2
Operating Safety-OS	90,1	92,3	92,9	93,2
Levelized Cost of Electricity LCOE €/MWh	12,3	15,4	18,4	19,8
Loss Of Energy Expectation, LOEE = MWh/year	2.165	2.764	2.636	2.867
Frequency of Loss Of Load, FLOL = events / year	17	15	16	14
Expected demand power but not supplied, EDNS = MW	3.201	2.834	2.603	2.305
Average Duration of Loss of Load, ADLL = hours	1,1	1,2	0,9	0,8
Energy Index of Reliability, EIR = € / MWh	5,6	4,6	4,9	4,3
Power production /supply balance distribution %	105,2	106,8	109,2	108,4
Lignite	62,82	31,49	28,95	19,30
Natural gas	15,54	29,57	27,46	32,15
RES	5,46	20,30	21,56	27,42
Hydro	9,53	6,64	9,81	9,95
Imports	5,45	11,99	12,20	11,18
Others	5,20	0.00	0,00	0,00

Source : Greek National Regulator of Energy or RAE

4.3. Performance/Productivity of Greek /REMTH's ESs

Energy efficiency is high on the political agenda, as all energy responsible entities seek to, reduce energy waste and GHG emissions and enhance energy security. In this context, it is important to have sound indicators based on well-structured data that help experts to investigate whatever helps/hinders energy efficiency. Energy Efficiency Indicators-EEI are used in overtime basis to monitor energy and environmental targets put in advance at national and regional level and to evaluate energy programs, projects, and policies, aimed to improving energy efficiency during the energy transition period. In order to be achieved the previous they are needed data that entered into simulation/forecasting models can predict with best accuracy future energy developments. The Greek EEIs are based on such relative European Energy Efficiency Indicators. Through these indicators, the trends in power consumption/saving/efficiency/reliability of an ES and different economic industries linked with the ES are summed up. In this way, the changes in energy efficiency indices are assessed at the whole and sectoral level throughout the country or region. These indicators based on a large number of parameters/variables are important since they are strongly related to climate and its changes caused by industry, agriculture, and lifestyle and show whether certain actions affect energy efficiency[15], [108]. For the modeling of these indicators, all the necessary quantitative and qualitative data collected, recorded, elaborated, and adapted in an adhoc timeseries. The basic sources for the data are, the Hellenic Statistical Authority (HELLSTAT), Public Power Corporate, Energy Regulator Authority (ERA/RAE), IENE and Eurostat. Indicatively for Greece and REMTH we will form, measure and calculate 8 indicators:

- **Primary energy intense indicator-PEII**: Expresses the total energy consumed to produce a unit of GDP: PEII = PE / (GDP / CC), where PE: primary energy consumption in Mtoe, GDP: GDP at constant prices of the previous year (base year 2005) CC: Rate for the conversion of current values to standard € values of 2005.
- **Final energy intense indicator-FEII**: It is the ratio of final energy consumption to GDP: FEII = FEC / (GDP / CC (2005)) * 1000, where, FEC: final energy consumption in Mtoe, GDP: GDP at constant prices of the previous year, CC: conversion of current values to standard € values of Indicator of Ratio of final energy intense to Primary energy intense R-FEI/PEI : Ratio of final consumption to primary energy consumption. Divergent trends between the two intensities are reflected by the change in the values of the index over time: R-FEI = RFEII.
- **Indicator of energy Efficiency to Entire Economy ODEX-EE**: ODEX energy efficiency indicators are used to measure energy efficiency in the main economic sectors, industry, transport, household sector and in all sectors of economic activity total final consumption. For each final sectoral consumption, the index is calculated as the weighted average of the individual sub-sector indicators. The sub-sectors are defined as the sub-sectors of industry and the tertiary sector: I / EE = ODEXi The ODEX energy efficiency index is more representative for the assessment of energy efficiency than the other indicators. The value 90 of the index, means a 10% improvement in the energy efficiency of the sector.
- **Sectoral Industrial Energy Efficiency Indicator-ODEX-INDT or SEIEEI**: The energy intensity of the industry per sector represents the ratio of the final energy consumption of the industry in Toe in terms of its Added Value at constant prices 2005: SIEEI = FCEi / (AVi / CC)) * 1000 where: EIS: Energy intensity of the sector FCEi : Final energy consumption of sector I, AVi: Value added of sector i, at constant values CC: conversion of current values to standard € values of 2005.
- **Transport Energy Efficiency Indicator -TEEI**: Energy intensity in the transport sector is calculated as the ratio of the sector's final energy consumption to GDP. EEM = TKEM / (GDP / CC)) * 1000 (Toe / € 2005) where, EEM: Energy intensity in the transport sector TKEM: Final energy consumption in the transport sector GDP: Gross National Product CC: conversion of current values to standard € values of.
- **Households Energy Efficiency Indicator-HEEI**: it is calculated from the quotient of the total energy consumption of the household sector in relation to the number of main house: HEEI = TECoH / NoH * 1000 UEC (Toe/House), where UEC/house = unit consumption of the household sector ECoH = energy consumption of the household sector NoH = number of houses. It is the most characteristic indicator in the household sector for measuring the improvement of energy efficiency.
- **Tertiary Energy Efficiency Indicator -TEEI**: it is calculated from the quotient of the total consumption of the sector, in relation to the Value Added of the sector at constant prices 2005: TEEI = EITS / (AVTS * CC). EETT: Energy Intensive of Tertiary Sector AVTS: value added of tertiary sector CC: conversion of current values to standard € values of 2005.

Table 18. Energy efficiency macro indicators for Greece and REMTH influencing the transition -Average of 2008-2017.

Energy efficiency macro indicators: 100= Best	Greece	REMTH
Primary energy intense indicator-PEII	89,6	87,4
Final energy intense indicator-FEII	82,3	80,3
Indicator of Ratio of final energy intense to Primary energy intense -R/FEI/PEI	1,08	1,09
Indicator of energy Efficiency to Entire Economy- ODEX/EE	88,4	86,6
Sectoral Industrial Energy Efficiency Indicator ODEX/INDT or SEIEEI	85,8	85,2
Transport Energy Efficiency Indicator -TEEI	76,2	76,0
Households Energy Efficiency Indicator-HEEI	92,8	88,4
Tertiary Energy Efficiency Indicator -TEEI	87,4	86,7

Sources: RAE overtime reports-HELLSTAT adhoc reports-IENE overtime reports-elaboration, adaptation, and compilation by author

Another important issue is the total productivity of energy and to the next table is presented it in overtime and comparative basis with 28 EU average values (table 19).

As it is seemed in table, Greece/REMTH, are behind the overtime 28EU average productivity values and for this new actions and policies are needed to boost it-we will refer to such policies to the next.

Table 19. The comperative productivity of energy resources of EU-28 and Greece/REMTH.

Year	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Greece/REMTH	----	----	1,1984	1,2034	1,2386	1,2147	1,2293	1,1826	1,2652	1,2706
EU countries	1,3874	1,4562	1,5242	1,4458	1,4773	1,5046	1,5428	1,5727	1,5351	1,5586
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Greece/REMTH	1,3722	1,0232	1,0745	1,2102	1,2783	1,2916	1,3090	1,3666	1,3787	1,3865
EU European	1,5773	1,5764	1,5984	1,7328	1,8218	1,7832	1,9123	1,9622	1,9819	1,9886
Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Greece /REMTH	1,3528	1,1237	1,0694	----	----	----	----	----	----	----
EU countries	1,5788	1,5798	1,6168	----	----	----	----	----	----	----

Sources: ARE/RAE overtime reports-HELLSTAT adhoc reports-IENE overtime reports-elaboration, adaptation, and compilation by author

4.4. Interventions for upgrading Cost-Effectiveness of Greek/REMTH's ESs

All experts agree that Greek/REMTHs ESs are old technology and need significant innovative interventions regardless the transition or not. Pioneering views from the 70's pointed out for Greece that-beyond organizational and technological level of Greek ES- a big problem is the low energy saving efficiency level, meaning huge amount of power waste-the greater in the eurozone-20-18th among 20 members. And this is the reason EU set as the best long-term goal the energy saving by 50% to all uses comparing to 1990, or energy consumption to be reduced by 40% per GDP unit in average terms till 2050. The above mean the energy potential saved quantity equal to 25.000 GWh/year for Greece and 850GWh for REMTH till 2050 (RAE/PPC/IENE reports). Thus, Greece/REMTH will have to improve strongly their energy saving efficiency, along with the promotion of RES. At the same time in two areas, anthropogenic activities related to energy have been found causing 78% of GHG emissions with high indirect cost in national economy. Thus, the improvement of energy saving efficiency will contribute to the reduction of primary energy consumption and nullifying GHG emissions and so that preventing climate changes. Yet, improvement of energy saving on the end use basis, will make possible to exploit in an effective way such latent costs, helping Greece/REMTH to reduce their energy dependence from imports. Further, the shift from low to high saving techniques and to renewable technologies, will enhance the innovation and competitiveness of Greek and regional economies as whole. Energy efficiency-the best outputs/least inputs-gives a clear picture regarding to how much cost-effectiveness is a spatial ES like REMTH's one [15], [108]. In order to be achieved the energy strategic goals set by EU-higher efficiency/lower emissions- from Greece/ REMTH, a series of targeted policy measures and interventions are envisaged, such as:

- Implementation of investments of € 8,2 billion by 2050, in the energy saving in buildings- the share of REMTH is € 387 million. –
- Increase penetration and integration of RES in buildings and infrastructure- through net metering system.
- Transport electrification and development of charging/storage infrastructures in order the share of electric vehicles (EV) in the new selling to rise to 30% in 2030, 55% in 2040 and 75-85% in 2050.
- Interventions in the buildings, as they are responsible for 40% of energy consumption and 67% of energy waste-they should be made more bioclimatic. According to the 2018 census, buildings are amounted to 5 million, of which 4.676.000 related to residential and 324.000 to businesses, offices, hospitals, and hotels ones. The corresponding ones for REMTH are, total 283.400, residences 243.560 and 39.840 the others.
- Interventions in lighting, heating, cooling, ventilation, and production process of firms, which are the second largest consumers after buildings.
- Boosting investments in energy saving of industry and private/public buildings.
- Effective implementation of regulatory measures and actions of the energy transition strategy, which are:

  1. Development of a plan for dealing with energy poverty.
  2. Introduction of ISO systems for energy management in public buildings.
  3. Upgrading the role of the Energy Manager in public buildings.

- Revision and improvement of technical instructions about the energy inspection of buildings. The basic rules boosted by technical specifications and methodologies aiming to increase the buildings operation with almost zero energy consumption and are.
  1. Intensification of energy saving actions through the programs, "Save-Become Autonomous" for the energy upgrade of the private buildings and "Electra", aiming to finance energy saving interventions in public buildings.
  2. Promotion of competitive procedures for achieving energy savings in specific sectors, such as the tertiary and industrial sector.
  3. Obligation by adhoc entities to save energy in distribution network operators and providers. They must ensure a 20% of the total cumulative energy saving target.
  4. Effective utilization of the National Energy Efficiency Fund-NEEF, as a basis for the development of new, innovative financial energy saving tools.
  5. Mobilization and leverage of private funds for investments in smart bioclimatic buildings and stimulating the building constructors to construct smart bioclimatic buildings in the country and REMTH.

All above strategic actions, beyond their positive impact on energy efficiency, can contributing to create good new jobs, by reducing operating costs and enhancing the competitiveness of construction businesses, using more environmentally friendly materials and intelligent control systems and management concerning the energy use.

4.5. Correlation among technoeconomic characteristics of Greek /REMTH's ESs

It is considered useful to investigate whether strong correlation existed between energy consumption and some energy structural parameters. It is known that the intensity of energy consumption is associated with cost-effective energy transition and power production technologies. In contrast to other studies, it examines the short and long-run bilateral relationship between energy consumption and ten variables- beyond technological innovation [123]. Other papers showed that, in short-run, technological innovation leads to an increase in energy consumption, while energy consumption has no significant effect on technological innovation and in long-run, energy consumption is positively and bilaterally related to technological innovation [124]. To this point we refer to our investigation the correlation between ten quantitative random variables- either non-linear, or monotonic dependence and calculate the degree of this relationship [5]. The data we have used to proceed statistical analysis are given to the next table

Table 20. overtime data for energy mixes, GHG emissions, RES share related to energy efficiency

Year /variables	**Firms with ISO 14000**	**Firms with EMAS***	**GHG** emissions**	**Recycling wastes %**	**Environment taxes % OF GDP**	**RES % in energy mix**	**Share of RES in gross basis energy consumption**	**Efficiency of energy resources**	**GDP in €2005**
1996	0	0	--	---	2,25	8,63	----	---	16.036
1997	0	0	---	9,2	2,25	8,63	----	----	17.059
1998	0	0	---	8,9	2,25	8,63	----	-----	17.631
1999	20	0	----	8,9	2,25	8,63	----	------	18.265
2000	42	0	11,87	8,8	2,25	7,76	2,4	78,0	19.285
2001	66	0	11,87	8,8	2,43	5,52	2,6	78,5	20.900
2002	89	0	11,81	8,8	2,17	6,63	2,8	80,5	22.719
2003	126	0	12,10	8,1	2,04	10,18	4,7	81,2	23.806
2004	173	0	12,13	10,1	2,06	10,06	6,9	82,4	25.426
2005	254	6	12,43	11,8	2,03	10,78	7,0	82,9	25.396
2006	259	27	12,04	12,8	1,93	12,76	7,2	84,2	28.273
2007	278	54	12,26	20,1	1,98	7,33	8,2	86,4	29.306
2008	463	59	11,90	17,7	1,89	9,14	8,0	87,0	31.161
2009	455	462	11,28	18,9	1,85	13,40	8,5	88,2	30.652
2010	560	819	10,71	17,1	2,44	18,34	9,8	89,0	26.626
2011	543	814	10,43	18,0	2,61	13,76	10,9	88,0	25.980
2012	657	795	10,15	19,3	2,74	16,70	13,4	88,0	23.456
2013	684	800	9,55	19,3	2,74	25,12	15,0	82,0	21.326
2014	701	786	9,22	21,4	2,79	25,28	15,3	85.0	19.807
2015	734	803	8,98	25,2	2,94	24,76	18,0	86.0	18.304
2016	727	823	8,21	26,3	2.98	25,23	18,3	86,8	17.345
2017	754	834	8,11	28.5	3.01	26,60	19,5	86.9	17.560
2018	761	852	8,00	31,4	3,02	27,00	20,4	87,01	17.890

Sources: RAE overtime reports-HELSTAT reports-IENE reports-elaboration, adaptation, and compilation by author

The correlation of every variable with the variable "energy efficiency" will become with the Pearson Correlation Coefficient (PCC) which gives the degree of linear dependence of two quantitative random variables, and it is given by formula:

$$r = (\sum(x-\bar{x})(y-\bar{y}))/\sqrt{((\sum x-\bar{x})^2(y-\bar{y})^2))}$$

There is also the method of Spearman Coefficient (SC) but in our case it is less useful than the PCC, because both variables are normal. Based on above data having a structured form of timeseries for 1996-2018, after a statistical analysis (PSSS) we result to:

Table 21. Correlation of some energy parameters with energy Pearson.

Energy Indicators and their correlation or impact to energy efficiency	**Pearson's coefficient**
Energy Dependence	71,8
Percentage of electricity in final household energy consumption	78,1
Electricity consumption for thermal uses in households	89,3
Industry energy intensity in value added and purchasing power parity	-73,2
Productivity of energy sources	65,8
Average price of electricity GHG emissions per capita	-88,9
Domestic energy consumption per capita	84,8
Number of firms certified by EMAS	85,5
Average CO2 emissions per kilometer from new passenger cars	84,1

Share of RES in gross final energy consumption	82,2
Share of RES in gross final homework energy consumption	90,7
Final oil products in in gross final homework energy consumption	81,7
Taxes related to environment as% of GDP Incomes coming from environmental taxes	-89,6
Incomes coming from environmental taxes to consumers	98,1

The above analysis allow us to identify the best efficient indicators, which reflect changes in improving the energy efficiency, and at the same time, they show the fields to which further interventions can offer the greatest potential improvement of energy efficiency and support energy policy decision makers to decide what will have to be done for strong facilitating the transition. It is noted that, among regions of a country there are significant differences. The differences concern, level of economic development, structure of economy- percentage of energy intensive firms, energy mix, GHG emissions/MWh consumed, different climate, differences to overall efficiency of energy conversion and industrial production facilities etc. The right interpretation of these indicators is very important, because it can give directions for effective structural changes so that Greece/REMTH to enjoy the best benefits for their ESs during the transition period. If $\boldsymbol{r=0}$: there is no linear relationship between X and Y, if $\boldsymbol{r=+1}$: there is a complete positive linear dependence and "an increase in the values of one, causes an increase in the values of the other, if $\boldsymbol{r=-1}$: there is a complete negative linear dependence, and if $\boldsymbol{r = close\ to\ -1\ or\ 1}$: indicates a negative/positive correlation, respectively, while values close to 0 do not have a linear relationship. The results of the table above mean that there is moderate to strong correlation among all variables influencing the energy efficiency.

4.6.The real viability/sustainability of Greek/REMTH's ESs

Viability is linked to the capacity of an ES to survive, which depends on its ability to fulfil its role in the context, by relating efficiently with other technoeconomic and production systems by developing relationships based on consonance and the possibility for these conditions to be maintained through time. The concept of survival introduces the variable time and a probability evaluation that requires the adoption of a long perspective, causing the interest of the energy entities on the necessity to evaluate the risk of survival of the ES. Sustainability is linked to the process of creation, maintenance and renewal that persists in equilibrium with the process of decline of an ES. According to such definitions, Greek/REMTH ES are sustainable/viable if they can meet energy needs at any time, in proper form at acceptable competitive cost and environmental impacts, with the best reliability and flexibility. To this, we give an idea about some factors of Greek/REMTH ES's that influence/burden their viability and sustainability with additional costs reducing their cost competitive advantages that should be avoided if there were better energy operations in real basis in hourly, weekly, and annual level. The most important technoeconomic elements of Greece/REMTH ESs are related to, quality of energy infrastructure, size and composition of its individual sectors, type, and use of different energy forms in power mix, average and marginal unit costs and its performance. The structure and development of their ESs are influenced by technological, economic, social, and environmental factors which determine their dynamism and potentialities. Greece/REMTH's energy future is steadily oriented towards electricity with RES as the main energy in power mix-additionally and temporally till 2040 in NG. It is adopted NG solution, as an interim transition fuel against lignite since it pollutes and contributes to climate change by 65% less than lignite. According to Greek experts, the imbalance between supply/demand is an index measuring the viability/ sustainability of Greece/REMTH's ES [34], [51], [54] (table 21).

Yet, viability/ sustainability of Greek/REMTH's ES's can be measured by comparing/ benchmarking of some key parameters and factors with respect ones of EU-28. Table 23 gives a picture of dynamism of the EU-28 ES's expressed through 18 adhoc indices [6], [28], [68], [69], [96], [97].

Table 22. The balance between total real power production/supplying and net power demand in Greece and REMTH ESs influencing their viability and sustainability.

Year	Net power demand of ES in GWh	Net power demand of ES in GWh	Annual change %	Total real power production capacity in GWh	Total real power production capacity in GWh	Per cent % of self-sufficiency of ES
Area	Greece	REMTH REMTH	%	Greece	REMTH	%
2008	55.675	2.780	---	56.310	3.300	101,8
2009	52.436	2.622	-5,56	56.490	3.310	107,8
2010	52.329	2.615	-0,20	57.545	3.268	110,1
2011	52.492	2.575	-1,60	57.915	3.344	110,4
2012	50.289	2.512	-2,34	58.611	3.386	116,5
2013	46.450	2.320	-7,63	58.664	3.498	126,2
2014	45.766	2.156	-1,47	59.228	3.125	127,3
2015	46.641	2.265	1,91	60.355	3.148	129,4
2016	46.478	2.304	-0,35	61.212	3.446	131,6
2017	47.202	2.603	1,56	63.932	3.892	135,4
2018	46.729	2.386	-1,00	65.462	3.543	139,9
2019	50.264	2.120	1,16	68.567	3.300	136,4
2020	48.765	2.095	-1,03	69.230	3.400	141,8
2030	56,760	2.870	16,0	74.300	3.500	130,8
2040	65,340	3.340	16,1	76.100	3.600	116,6

2050	73.460	3.730	12,3	78.000	3.800	106,3

Source: Greek Regulation Authority of Energy - RAE

Table 23. Measuring Greek/REMTHS ES competitiveness through comparing/benchmarking them with respect EU-28

Parameter-variable for comparing/benchmarking	Greek and REMTH	EU weighted	Benchmarking EU/Greece
1.Covering the energy demand by % of total based on power MW	106,2	109,3	1,03
2.Covering the energy demand by % by domestic power produced	86,6	93,2	1,07
3.Covering the energy demand by RES % in energy mix	30,2	21,2	0,70
4.Covering the energy demand by hydropower %	16,5	11,3	0,68
5.Covering the energy demand by NG %	24,5	17,6	0,72
6.Mean Weighted Performance of power sources in energy mix %	24.4	24,6	0,02
7.Variable power production costs+CO2 taxes in €/MWh	21,7	17,8	0,82
8.Marginal cost/ Marginal Price of System	22,9	16,7	0,73
9.Fexibility =time needed ES to respond to abrupt peak demand with the least cost, the less, the higher ranking	24,5	26,3	1,07
10.Reliability =total time of failures in hours/8.640 X100 in %	2,4	2,5	1,04
11.OPEX=€/MWh	22,8	23,5	1,03
12.Levelized Cost of power mix-LCOE	102,4	96,6	0,94
13.Mean Capacity Factor of annual weighted energy mix %	33,2	36,2	1,09
14.Emissions of energy mix -Mean value kgr/MWh	387,0	402,3	1,04
15.CO2 produced in tons in tons		xx	
16.Smart macro and micrgrids smart km/ total kmX100 in %	15,6	23,8	1,52
17.Telemeters to end-users/ total end-users X100 in %	2,6	14,5	5,57
18.Interconnections of grids countries connected/28 EUX100 in %	13,4	23,9	1,78

Source: Method proposed by author based on global literature

From the above table results that Greece /REMTH have worse efficiency in 1, 2, 9, 10, 11, 13, 16, 17 18 cases and have better in 3, 6, 7,8, 12, 14, 15.

4.7. The Greek/EU independent energy entities manage Greece/ REMTH's ES

The next 2 tables give a picture of Greek and EU independent entities evolved in energy systems and their role in energy transition roadmap.

Table 24. Greek independent entities evolved in energy systems.

Independent entity	Economic, administrative, and operational competences
Energy Regulation Authority -RAE	It is an independent administrative authority established in July 2000, which has been entrusted with the monitoring of the Greek energy market and consequently of the domestic energy market. At the same time, it monitors the operation of the Greek energy market in relation to foreign markets, especially those with which it is interconnected. RAE has the exclusive responsibility of controlling the other bodies LAGIE, ADMHE, DEDDHE and DEH. All independent bodies in the electricity market have administrative, financial, and operational autonomy
Independent Electricity Transmission Operator-IPTO/ADMHE	Established in compliance with EU Directive 2009/72 / EC in order to be the Hellenic Transmission System Operator. The operation, maintenance, and development of IAET to ensure the supply of the country with power in a safe, efficient, and reliable way. The formulate of the daily load forecast officially used by LAGHE for the construction of the Electric Systems.
Operator of the Hellenic Electricity Distribution Network - HEDNO/DEDDHE	The goals of AED are two: 1.The operation, maintenance, and development of the UNHCR in Greece 2. The ensuring transparent and equal access of consumers to the network
RES and Guarantees of Origin Manager-RES-GOM/DAPPEP	It focuses exclusively on RES and Co-generation systems, in collaboration with the respective producers and accelerates the effort to: 1. Ensure the viability of existing RES & CHIP investments 2. increase of penetration of new RES & RES-OG with ensured their viability 3.representation of RES & RES-OG in electricity markets of and environmental products for the benefit of both, the respective investors, and the consumers by setting affordable prices for them 4.tackling climate change and its consequences
Ministry of Environment and Energy (MEE)	It deals with all issues concerning energy, climate, and environment

Source: Greek Regulation Authority of Energy -RAE

Table 25. EU Independent entities evolved in energy systems.

Independent entity	Economic, administrative, and operational competences
European Commission-EC	Its main objectives are to achieve an energy strategy that will ensure a secure, competitive, and sustainable energy environment
Agency for the Cooperation of Energy Regulators (ACER)	Assists and coordinates the actions of national energy regulators at EU level and to work towards the integration of the single European energy market for electricity and gas
European Network of Transmission System Operators-E (ENTSO-E):	Represents 43 transmission system operators (TSOs) from 36 countries across Europe.

Source: Greek Regulation Authority of Energy -RAE

The above independent entities exercise all activities related to the power system, management, production/operation, development and maintenance of power production, transmission, and distribution to all types of end-users.

4.8. Greek stakeholders evolved in Greek/REMTH's energy systems

Table 25 gives a clear picture of stakeholders evolved in energy systems-exempt local societies and their role in energy transition roadmap.

4.9.The CO2/GHG emissions and actions to reduce their impacts on climate

GHG's are gases that, absorb and emit radiant energy within the range of infrared radiation and trap earth-heat causing the greenhouse effect. The main GHG's in atmosphere are, steam, CO2, methane nitrous oxide and ozone. Without GHG's the average temperature of the earth's surface would be about -18 Celsius, instead of the current average of 15 ºC. CO2 has the greater impact on climate, and its production is due to human activities. Other GHG,s emitted in smaller amounts, but they trap heat much more efficiently than CO2. The next two tables give a picture regarding the GHG's impacts on climate. These GHG are responsible for the deterioration of climate after 1980, meaning higher temperature by 0,6 ºC (2020) and more often extreme weather – typhoons (table 26).

EU aiming to prevent irreversible climate changes has pledged to achieve climate neutrality, or an economy with almost zero GHG emissions by 2050. Tables 28,29 illustrate how it will be done.

The adhoc proposals by EU in order to be achieved the above goals are:

- **Introduction of Emissions Trade System-ETS in industry**: aims to reduce CO2 emissions from industry, forcing companies to pay an adhoc tax for each ton of CO2 they emit. The trade is done through auctions while there are incentives to push clean innovation in industry. ETS is the first global GHG reduction market and remains the largest. It regulates about 40% of GHG emissions and covers approximately 11.000 power plants in the EU-28, 247 in Greece, 2 in REMTH. Its goal is to reduce emissions dramatically till 2050 compared to 1990 and 2005 [13], [72], [74], [104].
- **Introduction of Emissions Trade System-ETS in other sectors beyond industry**: Some sectors do not be covered by ETS-transport, agriculture, infrastructure, and waste-still they account for around 60,2% in EU-28,58% Greece, through adhoc model for REMTH is estimated 55,6%. Emissions from these sectors will be reduced by 30% till 2030 compared to 2005 rates. This will be achieved through the achievement of the nationally set targets, which will be calculated on the basis of GDP/capita. EU countries with lower incomes will receive support from EU.

Table 26. Stakeholders evolved in energy systems.

Roles	Roles' description	Entities-organizations	Number	Percentage %
Power producers	To substitute thermal plants with RES	Public : thermal and RES Private: thermal and RES	1 5	63,5 36,5
Electricity transmission system	To substitute/upgrade today grid system with a new smart one	IAET, AED, ARE-OG	1	100,0
Energy contribution - low voltage	To substitute/upgrade today grid system with a new smart one	IAET, AED, ARE-OG	1	100,0
Wholesalers	To ensure stable reliable and low cost power to retailers	Public Private	1 7	51,9 48,9
Retailers	To ensure stable reliable and low cost power to end-users	Public Private	3 10	55,8 43,2
Energy Stock Market	To operate cost-effectively ensuring reliable and low cost power to end-users	Public	1	100,0
Day ahead market and Intraday market (spot markets	To operate cost-effectively ensuring reliable and low cost power to end-users	Public	1	100,0
Forward market	To operate cost-effectively ensuring reliable and low cost power to end-users	Public	1	100,0

Roles	Roles' description	Entities-organizations	Number	Percentage %
Balancing market: reserve and energy markets	To operate cost-effectively ensuring reliable and low cost power to end-users	Public	1	100,0
Ex post settlement of imbalances	To operate cost-effectively ensuring reliable and low cost power to end-users	Public	1	100,0
Total		Public	35	100,0

Source: Greek Regulation Authority of Energy - RAE

Table 27. GHG emissions in Greece /REMTH in sectoral basis-data have levelized, compiled and adapted.

Type of pollutants/percentage %	EU	Greece	REMTH
Power production + transportation	80,70	81,45	78,56
Manufacturing firms	7,82	5,45	5,32
Agriculture	8,72	9,86	10,65
Wastes management processes	2,75	3,24	5,47
Total	100,00	100,00	100,00

Sources: IEA report 2019-IENE report 2020- RAE report 2020-elaboration, compilations, and adaptation by author

Table 28. Pollutants emission – 2017.

Type of GHG/percentage %	EU	Greece	REMTH
Dioxide carbon CO2	81,00	82,00	79,00
Methane NH4	11,00	12,00	13,00
Nitrogen oxide N2O	5,00	4,50	7,00
Hydrophthorcarbos	3,00	1,50	1,00
Total	100,00	100,00	100,00

Sources: IEA report 2019-IENE report 2020- RAE report 2020-elaboration, compilations, and adaptation by author

- **Reduction in transport emissions**: Transport is responsible for almost 30% of total GHG emissions in the EU, of which 72,3% comes from road transport-in Greece they are 27,8 and 77,4% respectively. Vehicles are responsible for 15% of CO2 emissions in the EU and 28,6% in Greece, for REMTH 17,3%. The EU has adopted stricter car emission standards and is calling for new measures to facilitate the transition to EV with the aim of reducing transport emissions by 65% till 2050, comparing to 1990. A question has arisen, how clear and sustainable solution are the EV's. The answer is that EV's are more environmentally friendly during their operation life cycle-by 98,5%, but more polluting during their manufacturing-by 38,6% (www.cmu.edu/cit/veg - Jeremy Michalek-412, 268-3765). There are two ways to reduce CO2 emissions from cars, either by increasing their efficiency, or by changing the fuel. Today, the majority of cars in EU use oil (EU =52,1%, Greece= 34,7%, REMTH= 32,0%), but EV's are gaining share market. Sales of battery-powered EVs in the EU increased by 65% and 72% respectively in 2019 and 2020. With the real increase in the share of RES in power mix, EV are expected to become less harmful to the environment. Table 30 gives a clear picture regarding the transportations 'emissions.
- **Increasing the forests' positive contribution to climate:** Forests in the EU absorb 8,9% of the EU's total GHG emissions-6,4% of Greece, 8,5% REMTH. The EU has to prevent GHG emissions caused by deforestation by forcing every EU country to compensate for changes in land use which led to increased CO2 emissions through better forest management and growth.

Table 29. Legally binding goals for emission reductions by 2020-2050.

Year/reduction goals %	Reduction of GHG emissions %	Increase of RES in power mix	Increase of energy efficiency KWh/ 1000 € GDP	Increase of smart grids and interconnection %	Projects for improving climate	Reduction of CO2 emissions by vehicles %
2020	-20	≥20	≥10	10	20	----
2030	≤-40	≥37	≥32,5	15	25	37,5
2040	≤-55	≥85	≥55	65	50	75
2050	≤-55	≥95	≥55	75	65	85-90

Source: Mathas, E. (2010), "Life Cycle Analysis Methods"

Table 30. Actions to reduce emissions.

Actions and measures to reduction of GHG emissions and estimation of their contribution in reduction in % basis	Percent %
Sustainable and secure energy supplies through diversification of energy sources-increased RES share	12,4
Accelerated of RES penetration towards increased energy supply diversification and affordability	9,7
Sustained growth of trade in energy among 27 EU countries	8,6
Increased energy efficiency and saving in all sectors, including buildings and transportation	8,1
Enforcement of standards for the introduction of electrical appliances as well as standards for vehicles importation	7,7
Increased investment in production, transformation, and distribution of viable RES	7,5

Actions and measures to reduction of GHG emissions and estimation of their contribution in reduction in % basis	**Percent %**
Strengthening of the human and institutional capacities in the EU energy sector	7,1
Careful expansion of power generation, transmission, distribution, and trade	6,5
Access to affordable energy by the poor and vulnerable people	6,2
Greater use of electricity generation by RES in the transportation, industrial and agricultural sectors	5,8
Optimal establishing an institutional frame for leveraging financing mechanisms for the development of viable RES	5,4
Increased technology transfer and information sharing systems-cloud, IoT	4,8
Established both regional and national targets for GHG emissions reduction	4,1
Strategies for maintenance of adequate energy reserves in the event of disasters or peak demand	3,8
Strengthened R&D and innovation efforts in energy sector especially in areas of RES technologies	2,3
Total	100,0

Source: EC/EU report: 2030 Climate Target Plan, adhoc report 2019-calculations, adaptations, and compilations by author

Table 31. Break - down of transportation emissions -Year 2016.

Transportation means	**E.U. %**	**Greece %**	**REMTH* %**
Cars	32,7	42,2	39,4
Lorries	26,2	20,7	18,2
Trucks	11,9	10,2	13,4
Motorcycles	1,2	2,9	2,0
Total of road transportations	72,0	76,0	73,0
Ships	13,6	10,0	9,8
Airplanes	13,4	13,2	12,8
Others	1,0	0,8	4,4

Source: European Environment Organization *Estimations are based on national data and have been calculated after same adaptations and compilations by author

4.10.Contribution of energy sector to Greek/REMTH's socioeconomic growth.

4.10.1 General approach to energy's developmental contribution.

Societies' well-being, economy competitiveness and the overall functioning of nations/ regions are dependent on safe, secure, sustainable, and affordable energy by more than 50% [75], [76]. EU draws a Sustainable Development Strategy-SDS aiming to ensure energy security of supply, protect climate via policies and adopt a number of regulatory measures able to support a low-carbon economy based on innovative energy technologies, which will maximize impacts on the energy markets structure. EU has also endorsed ambitious GHG emission reduction targets accompanied by the decarbonization of the total economic sectors. To this direction, EU policy-makers provided member states with a set of smart energy models that, under a number of distinct assumptions, lead to stronger growth of national/regional economies. These models take into account possible contributions of innovative low-carbon energy resources and energy conversion schemes, both on the supply/demand sides. The models analyze future emission reduction pathways, the policy instruments to attain them and an estimation of the mitigation costs, in view of the post-2020 EU frame on climate change.

Greece/REMTH have significant natural resources and their greater exploitation is easy and cost-effective. There is a well-measured high wind, solar, hydrodynamic, geothermal and biomass capacity unexploited so far. In Greece, the essence of the transition focused on the tetraptych, decarbonization, digitalization and decentralization-electrification -DDDE. The development of RES, the introduction of energy saving techniques and the significant progress of electrification and digitalization of its economy are the main axes for the promotion of transition and strengthening of socio-economic development. Decarbonization through increased share of RES contributes to independence from imported and strong polluting fossil fuels ensuring lower power prices for end-users. Digitalization can generate competitive advantage for ESs offering greater solutions for process optimization, customer satisfaction through digital transformation and new business perspective to entities involved in power issues. Decentralization of power production via greater share of RES in power mix leading in more spatial balanced growth, more smart grids/microgrids, more local technological added value and easier meet of local power demand [5], [18], [28], [114]. Electrification exempt its great contribution to climate, creates new challenges and opportunities for growth in the Greek energy market. Electrification in transport, buildings heating/cooling with pumps and agricultural works are technological practices that are expected to become commercially viable on a large scale soon.

The transition process based on above four drivers, combined with the further penetration of RES and green H2 production expected to be the main six drivers attracting large scale investments-€ 9 billion till 2021-2030 for RES and €2,5 billion for green H2 - that will contribute to greater growth rates. The withdrawal of existing lignite plants by 2025 from power generation will strengthen the role of NG temporally and RES permanently. It is noted that the energy sector includes activities with great sectoral growth leverage, either in supplementary or synergy basis. Activities such as, smart power generation stations from RES, combined by smart transmission, distribution, supply, storage systems and distribution microgrids infrastructure for facilitating RES dispersing installations. Yet, strong local added value will produce the induced economic activities of repairing/ maintenance services, inspections, consulting, and ITC services are linked indirectly with energy sector. All that are very useful developments for REMTH because are enabled to create many well-skilled direct and indirect jobs [121]. According to an adhoc study made by IENE in 2020, the today employment and the future one predicted by projections are given to the table below.

Table 32. Today employment in energy sector in Greece and REMTH and future trends.

Energy sector/employees	**2018**	**Future trends up to 2050**
Oil	29.542	Decreasing annually by 3-6%

Energy sector/employees	**2018**	**Future trends up to 2050**
Mining /Production	4.287	Decreasing to 3.500 in upstream processes-oil mining
Oil refining procedures	4.971	Great decrease of employees, about 2.000 due to automations, and lower demand-greater demand for new specialties
Oil wholesales trade	2.269	Decrease of employees from 2.269 to 50
Oil retailing trade	18.015	Decrease of employees from 18.015 to 3.500 and it will increase the occupation to electric fuel
Lignite mining	4.437	Almost 0, since the mines will close up to 2028
Electricity generation, transmission, distribution	24.998	Moderate increase of demand for new specialties, about 2.000 regarding systems reliability, smart grids safety, energy saving, energy performance, electricity smart systems repairing
NG production, distribution Co-production heat and electricity	2.674	Moderate increase of demand for new specialties, about 1.000 regarding pipelines safety, energy saving, energy performance, NG systems repairing
Co-production electricity-heat and Electricity	419	Increasing to 650
RES systems	14.600	Increasing by 1-1,5% annually
Solar systems	3.500	Increased by 200 in new specialties and skills
Photovoltaic direct, indirect	2.200	Decreasing to 1.500 in upstream Ph/V processes
Wind turbine systems	2.500	Increasing jobs by 1.000 through increased demand for new specialties and skills
Hydro, all sizes	2.200	The same, upgradation of competences
Biomass	2.600	Increasing by 1.000 in new specialties and skills
Biofuels	700	Increasing by 200 in new specialties and skills
Biogas	100	Increasing by 200 in new specialties and skills
Geothermal	200	Increasing by 150 in new specialties and skills
Energy performance +energy inspectors	7.500	Increasing by 1.500 in new specialties and skills
Recycling and energy exploitation	2.200	Increasing by 1.000 in new specialties and skills
Energy entities and research centers	360	Increasing by 300 in new specialties and skills
Total employment	86.640	In general, increasing trends

Source: IENE report 2020, EurObservER report 2019, Ministry of Energy overtime reports, adaptations, and compilations by author.

Further, the energy sector can play an important role in the pursuit of a new innovative growth model for Greece/REMTH. The higher performance of energy will have direct- concerns its contribution to higher value added and employment- but also indirect- concerns wider and strongly affecting on the competitiveness of other productive activities. The table below presents the interdependence among growth and factors contributing to REMTH's development rates which are correlated directly/indirectly with energy.

Table 33. REMTH's development factors related directly, or indirectly to energy.

Factors related to energy and contributing to development	**Contribution as %**
Business expenses for R&D	37,9
Household electricity consumption	28,9
Industrial production index	7,9
Total electricity consumption	4,8
Degree of utilization of manufacturing firms capacity	3,8
Electricity consumption by energy-intensive manufacturing firms as a% of total electricity consumption by manufacturing firms	3,7
Electricity consumption by means of transportation	3,6
Electricity consumption by all manufacturing firms as % of total energy consumption	2,8
Profitable companies as a% of all of them	2,5
Energy-intensive firms as % of total ones	2,2
Construction of new houses as % of previous year	1,8
Total	100,0

Source: Stathakis et al (2015). A study on the contribution of 12 key-factors to the growth rates of the REMTH by using a Neural Network Model Paper, 2015

In terms of Value Added **(VA),** the energy contributes to national basis about € 6 billion, a size that corresponds to about 3% of domestic VA-the respect values for REMTH are €360 million and 4,1% respectively. Finally, the so far transformation of energy sector created 45.000 new jobs, or 1,2% of the Greek workforce - the respect values for REMTH are 1.875 and 2,3%. The next table presents the contribution of energy sector to gross added value and employment.

Table 34. Gross added value and employment in energy sector - 2018.

Gross added value of energy sector	**Greece %**	**REMTH %**
Electricity and NG	2,6	2,6
Oil refinement	1,7	1,7
Fuels trade	0,6	0,4
Total	4,9	6,8
Employment	Greece %	REMTH %

Gross added value of energy sector	Greece %	REMTH %
Electricity and NG	2,2	4,3
Oil refinement	0,3	0,0
Fuels trade	2,0	2,0
Total	4,5	5,7

Source : HELLSTAT reports 2019-provisional data, adaptation, and compilation by author.

The greater VA and new jobs come from electric sector 58% and 42% by NG. It is noted that, Greece's trade deficit in energy products was: € 4,5 billion in 2018 and 4,7 in 2019, 4,6 in 2020 and 4,5 in 2021.

Another important factor of energy is its contribution to higher growth rates via its relative low prices to cost productivity of rest economy sectors-the energy in Greece consists of the 8,7% of the total production cost for the certain GDP of 186 billion. Bean (2014) claimed that energy cost productivity has more positive impact on total national economies than energy intensity. The higher energy cost productivity, the higher cost productivity of total economy. The energy intensity is often used as an indicator of energy efficiency because, at an aggregate level, it is a proxy measurement for the energy required to satisfy/meet the energy services demanded. The fact that this indicator is relatively easily available to evaluate and compare countries or regions of a country makes it very useful. But a country with relatively low energy intensity does not necessarily have high energy efficiency. The growing importance of energy costs the last year is due to the significant rise in energy prices at the wholesale and retail market level-new energy crisis due Russia-Ukraine dispute. Oil product prices increased cumulatively in the period 2019-2022 by 85%, while electricity and gas prices by 96% and 97% respectively. Other factors playing a role in impact of energy sector to others are, the structure of the economy, the share of energy-intensive firms in total ones, the spatial geographic characteristics, the overall climate and weather conditions and the quality of transportation means. It will be an omit if we didn't refer to the relationship between energy cost-productivity and the level of technological innovation in Greek/REMTH economies. Empirical studies have proved the tight relation with r=0,812 [123], [124]. So, improving energy cost-productivity and competitive conditions means that there is a respect boosting of cost-productivity and competitiveness of the national/regional economy and industry as a whole. It is worth noting that, changes in retail prices were higher compared to wholesale prices due to significant increases in taxes and other charges over the same period-fact with bad impacts on Greek/REMTH's standard of living.

4.10.2 Some adhoc views about the contribution of energy to REMTH's growth

Analysis regarding the adhoc finance investments towards REMTH's green transition was based on both, the processing of collected data and the searching of relevant literature. We note that some data and information were gathered through interviews with energy experts in REMTH. In the region the required is the reform of energy mix in order to be achieved the national and regional energy transition targets deriving from the NPEC. for RES and is expected to have major implications for the economy and employment in the energy sector.

To this point it is worth to formulate and implement an integrated approach for estimating the employment benefits associated with the exploitation of RES in the power sector. The best method is the input-output/Leontief that can calculates direct and indirect employment effects. Also it builds up techniques and makes all the necessary modifications in order to take into account the specific conditions of the RES market but needs many data that is difficult to be found in regional basis. The figure below shows the distribution of the probability, a newly employed person to be drawn from the pool of previously unemployed workers in relation to the unemployment rate of the economy.

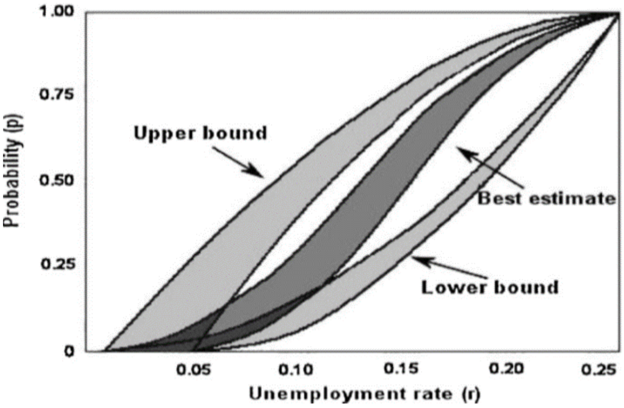


Fig. 12. Unemployed workers in energy due innovations in relation to the unemployment rate of the total economy. (Source: Haveman and Krutilla-2011).

All investments aim-exempt to promote to green transition- to sound the growth rates, therefore the employment. According to reports issued by the International Labor Organization and the World Economic Forum (ILO 2018, WEF 2020), a growing number of green jobs will be created, as the transition to a more sustainable low-carbon economy will lever the spatial economy. The estimated employment was calculated by taking into account both, the appropriate employment rates from the international literature and the two reasonable power generation scenarios for Greece, developed by the E3Mlab (National Technical University of Athens. Both scenarios include actions to greatly increase the penetration of RES into the power mix. Each scenario includes a projection of electricity generation and installed power from 2010 to 2050 taking 2019 as the reference year. It was not considered appropriate to include a scenario without RES promotion measures [12], [15], [28], [65], [102]. The results do not quantify all the effects of employment but provide a framework for comparing job creation from RES and NG by calculating indicative employment rates per technology in electricity. It is based on rates of direct, indirect, and entailed employment, in years of work per GWh, for different energy sources [15].

According to the American Enterprise Institute some useful data about future green jobs' creation are the following: the future RES technologies, the regional economic drivers and the diverse including professional scientific services. According to Alvarez et al., (2009), jobs destroyed elsewhere in the economy for every green job subsidized, is calculated by the following equation (http://www.aei.org): «Destroyed jobs/every green job subsidized =Annual subsidy to RES per worker/Average productivity per worker».

From the above equation and considering that: a. the average subsidies to RES electricity is 19 €/MWh in weighted basis for P/V and W/T b. the average productivity per worker in Greece was € 65.850 according to the OECD (2019), the number of jobs destroyed elsewhere in the economy for every green job subsidized can be calculated. This calculation have been based on the future electricity generating mix-different mix=different results, the existed data lead to results: a. in period 2021-2025 the destroyed jobs will be more than the new created and defined by the portion 1/0,85 b. the period 2026-2035 the destroyed jobs will be less than the new jobs created and defined by the portion 1/1,22 c. the period 2036-2050 the destroyed jobs will be almost equal to new jobs created and defined by the portion 1/1,01.

The above mean that, annual employment for each power generation technology is calculated as a function of the annual production in GWh and the corresponding employment rate. The sectors that will contribute the most to direct employment in all scenarios are the NG, P/V and wind parks-less the offshore wind parks. In 2030, the P/V and onshore wind parks will be the ones that will contribute the most to employment, while in the scenario of rapid delignitification, the sectors of P/V, wind parks, large hydroelectric plants and NG will have the largest contribution.

In indirect employment, P/V and NG will have the largest contribution in the reference scenario, something that will also apply to the de-lignification scenario.

In induced employment, the sectors that will contribute the most in the year 2030, in all scenarios, are primarily the NG and the P/V. The trend for the year 2030 continues till 2050, under the condition that RES technology and performance will increase in linear way, without any abrupt breakthroughs. Comparing the total employment resulting from the two scenarios it is observed that, the rapid de-lignification scenario and its replacement by NG in electricity generation, yields less benefits in terms of employment. This can be attributed to the low overall employment rate in the NG sector, compared to that for lignite plants [88], [91], [92], [93], [94], [95], [96], [97].

In conclusion, the restructuring of the energy mix in Greece and REMTH through the transition is expected to have not only quantitative but also qualitative effects on employment. The planned investments in the energy sector can offer a significant boost to employment. However, the RES incentives will boost employment, exempt if significantly unpredictable technological breakthroughs by 2050. The energy sector can contribute to the alleviation of unemployment, in particular through the supply of specialized jobs, since:

- It is offered for the creation of highly specialized jobs in the private, research and public sector. -It employs a significant range of professionals such as, providing specialized legal and general consulting services, development of modern information systems, accounting and financial support of actions or provision of logistics services.
- The timely development will attract many and good FDI's and will help the extroversion of Greek energy companies by creating thousands of new jobs. The next table gives the estimated employment effects related to the use of RES technologies in Greece, according to equation mentioned to this part of work and to literature.

Table 35. Estimated employment effects related to the use of RES technologies in Greece (in man-years/MW).

Type of works	**CAPEX-W/T**	**OPEX-W/T**	**CAPEX-P/V**	**OPEX-P/V**
Direct	0,55	0,63	2,12	0,78
Indirect	0,24	0,17	0,92	0,17
Induced	0,16	0,18	0,63	0,24
Total	0,95	0,99	3,67	1,18

Source: Tourkolias, C., Mirasgedis. S. (2011). "Quantification and monetization of employment benefits associated with renewable energy technologies in Greece Renewable and Sustainable Energy Reviews 15 pp. 2876– 2886.

4.10.3. EU/Greece: how should they cope with this energy crisis: returning to fossil fuels or accelerating the transition.

Many energy experts stress that the existed energy technologies are not yet cost-effective and on a scale of implementation, involving precariousness during the transition period, so more realism is needed.

Firstly, despite the current fluidity due to energy crisis, the goal to protect our planet from the climate crisis must not be loosed. EU has to remain fully committed to the green transition which is the only best solution. If today RES participated by 60-70% in electricity generation mix-a goal for 2030, electricity generation should increase by 40% and end-users would enjoy much lower energy prices. Another difficult goal is emissions reduction by 0-5% till 2050 so that global warming to remain below 1,5 degrees Celsius until the end of the century.

Secondly, the high energy prices could make transition politically difficult for some EU countries, they prefer a more low rate in transition than faster one. Doing simultaneously both-increasing electricity generation and reducing coal/lignite-will require huge RES penetration to power mix, especially P/Vs and W/Ts, combined with large-scale storage systems. But within this huge energy crisis, coal enjoys its great comeback, while RES meets difficulties due to a combination of logistical problems posed by the trade war. Nor solar/wind systems can be easy installed into 2022 for many self-evident reasons. Thus, this process proves the existence of an asynchronous transition, as RES are not developed enough to replace the coal/lignite that must be removed from the system. There is this period of embarrassment, before the EU can completely switch to non-fossil fuels.

Thirdly, it points to the large increase in electricity demand in 2021, as the global economy has recovered from the pandemic. RES cannot respond to such increases in energy demand because storage systems' capacity is not yet at these levels, and the few investments in fossil fuels also contribute to energy instability and high prices. The system generally has fewer possibilities to cope with these ups and downs. In conclusion, our proposal is EU/Greece to increase and accelerate investments to both, more RES based on new technologies and faster installation processes and temporal use of coal/lignite-till end of 2023-so that to be balanced better between power supply/demand, [5], [18].

The next table gives valuable information about the today energy mix in operation basis and degree of capacity exploitation by power technology in the national/regional level. From its data we see that nontechnology overpass its 90% of real capacity, implying that there are potentials for more production even by today sources in rather higher cost/MWh.

Table 36. Penetration of power in the national and regional level by power generation technology.

Type of energy power /hourly penetration	Greece/hours	Greece % penetration	REMTH /hours	REMTH % penetration
Lignite stations	1.556	18,0	0,0	0,0
NG stations	4.222	48,8	3.965	57,8
Hydropower Nestos	5.024	17,4	3.987	58,0
W/T > 30%	1.235	14,3	1.304	18,9
W/T > 50%	429	5,0	508	7,4
P/V> 30%	1.654	19,1	1.457	21,2
P/V> 50%	325	3,4	209	3,0
Total thermal	5.778	66,8	3.965	57,8
Total RES	2.862	33,2	2.798	40,7
Total of all in average terms	8.640	100,0	6.875	100,0

Source: RAE reports 2015-2021, DEDDHE reports 2012-2021

4.10.4 The ability of REMTH's energy sector to attract and leverage investments

The production and distribution of electricity is directly related to the economic and social development of the country, which requires the formation of an integrated investment, energy and environmental policy based on clear goals and schedules, so that there is a transition to an economy with almost zero fossil fuels. Until recently, the one-dimensional solution of the country's energy and investment policy has caused major distortions in the energy market and has been a real obstacle to the development course of Greece/REMTH. A new energy and investment policy should promote simultaneously many goals.

- Creates Greek added value to ensure the sustainability of investments. Along with the financial incentives granted for investments in the energy sector, the removal of institutional disincentives is required.
- Has a clear institutional framework to lead to safer investments and so there is a fact, prices to be lower for the benefit of society as a whole. An independent legal framework for each form of RES would simplify applications with the benefit of time and money.
- Promotes clear competition, by redefining tariffs for RES, based on the same principles, the same data, and transparency.
- The new investments should contribute to the increase of employment and the creation of Greek added value in constructions.
- Promotes investments to increase energy productivity and competitiveness, through clean energy technologies and, at the same time, ensures regional development.
- Promotes investments for energy saving and demand management. Saving is a unique, inexhaustible, and untapped energy deposit, the largest in the country.
- Promotes dispersed production through small modern power plants, or cogeneration plants including hybrid systems.
- Supports the development of domestic manufacturing and technology. Via the new investment law 4887/2022 will have to be attracted investments in energy sector that should strengthening the domestic production base-construction of wind turbines and photovoltaic systems.
- Promotes a modern technical legislation with the necessary mechanisms for interventions in the GBR and the national urban legislation. Obligation to install photovoltaics in new buildings-bioclimatic- to cover at least the heat/cool conditioning loads.

In the future, investments in energy infrastructure will need to be scaled up significantly to support, the broader development, the economic and climate agenda in Greece. Given strains/shortages on Greek public finances, engaging private sector capital will be the key for new greater investments. Obstacles emerged from energy market failures, including the lack of supportive policies to RES, will have to be upgraded. A key challenge for Greece to catalyze investment flows in RES is to design and implement clear and predictable domestic policy frames. In Greece, sectors covered by the policy guidance for attracting investment in clean energy infrastructure are:

- **Smart investment policies**: Non-discrimination in taxing of FDI versus domestic investors, intellectual property rights - what steps Greek government will take to protect intellectual property rights for clean energy technologies, effective contracts enforcement. It will be created a market mechanism to price carbon. A well-functioning Greek financial market can contribute to enhancing investment opportunities for both domestic and FDI's.
- **Smart financial sector development**: Adhoc financial tools, capable to strengthen Greek financial market, easy access to finance sources for every size of firms, non-discrimination in taxing of FDI versus domestic investors.
- **Smart investment promotion and facilitation**: Greece has to set long-term policy goals, smart incentives for investments, smart CO2 pricing, removal of all fossil-fuel subsidies, policy coherence and coordination, smart licensing.
- **Competition policies**: Greece has to set favor innovation incentives contributing to attract new large-scale investments and sound competition policies to allocate the wider benefits of investments to society.
- **Improve of regulatory quality of the electricity market, cross-cutting issues**: are two dimensions of public governance that critically matter for the confidence and decisions of all investors and for reaping the development benefits of investments.
- **Recovery-Resilient Fund-RRF:** is the basic financial tool for investments, managed € 57,5 bil, much of which will be allocated to green development projects. The responsible authorities, according to NPEC, will have to promote in due time the RES and the de-lignitification in order to be financed by RRF. The table below presents the capital sources of RRF available for green transition-beyond the other financial sources.

Table 37. Financial sources of RRF available for green transition.

Investment resources in million €	Greece - € of RRF	REMTH - € of RRF	Greece total	REMTH total
Energy transition	1.200	72,8	2.574	154,5
Buildings upgrading and land planning reform	2.544	101,8	4.279	191,2
Transition to green transportation	520	20,2	1.197	48,0
Other actions for industries, etc	1.772	88,6	3.345	167,2
Total	6.026	283,4	10.395	560,9

Sources: Ministry of Economy-compilation and adaptation in regional basis by author

The required key-energy investments by 2050 are estimated to € 86 billion, with the main part of them, 82,3% will be invested in upstream activities, RES, electricity and green H2 production, energy saving and transport electrification and 17,75 to downstream activities.

Table 38. Key - energy investments planning till 2050.

Sector / Investments in million €	Period	Greece	REMTH
Electricity			
Upgrading of all technologies power generation and their infrastructure	Up to 2050	18.100	650
Smart grids	Up to2040	17.600	400
Smart meters	Up to2030	400	15
RES infrastructure			
New P/V farms in MW	Up to 2050	2.300	110
Investments in new P/V in million €	Up to2050	8.800	350
Concentrating Solar Power Systems (CSPS)	Up to2050	900	20
Wind parks in MW	Up to2050	3.400	240
Investments in new wind parks-inshore/offshore in million €	Up to2050	28.000	960
New hydro small and upgrading of large scale power stations	Up to2050	400	15
Biomass (including liquid biofuels)	Up to2050	3.100	45
Geothermal	Up to2050	1.300	75
Pipelines and NG			
New and upgrading NG power stations	Up to2040	1.800	800
Trunk Pipeline and Grid Expansion	Up to2030	5.400	205
LNG: including Alexandroupolis FSRU	Up to2030	2.000	450
Revithoussa expansion and UGS	Up to 2030	2.800	000
De-lignitification	Up to2028	1.400	000
Upstream and Downstream projects	Up to 2028	4.000	30
Total	Up to 2050	96.000	6.300

Source: Source: Ministry of Energy and Environment 2020 - IENE study "Southeast Europe Energy Outlook 2016-2017", adaptations and compilations for REMTH by author.

5. Sub-part C: Necessary conditions for a cost-effective transition

5.1. The changes of power demand during transition: a regression model for forecasting future power demand

Energy planning, in short/mid /macro-term, essentially means to forecast power demand, peak/least demand and supply for both, the economy as a whole and by sectoral level. Energy projects are high cost and time-consume(construction period is 5-10 years), so they need the best planning and forecasting models with the best accuracy. If the forecast is wrong then there will be, energy shortage, costing much more than energy could be lost, or energy surplus implying a high capital cost spent in needless energy projects [5], [15], [18], [90]. So, accurate planning/ forecasting means: correct energy planning at any time of period, measuring all the financial, technical, technological, time-related risks, keeping data for energy supply/demand for a long period of time. Errors in energy supply/demand forecasts are inevitable and often deviate from actual values due to constraints on model structure, or non-targeted assumptions. The advantages of forecasting methods are, their contribution to the right decision making and the right planning and, if the data is of high quality, the forecasts can also be accurate. The models used to this work estimate future energy demand in each important sector of REMTH's economy. Energy demand changes as a function of energy prices and future macroeconomic variables, demand profile, peak/least demand, electricity price spikes, energy-intensive, energy performance, consumers profile, climate/weather conditions, bordering energy exchanges, supply/ demand balance control, variable/fix/marginal costs GDP, structure of GDP, GDP/capita, income elasticity, etc.

Our model is simple and takes the general form $y = F(x, p)$, where $X =$ input vector, Y=output variable, F=connecting function and p=parameter. The model based on timeseries logic using a simple deterministic process, although it should follow linear interpolation, or complex stochastic process after some necessary adaptions. Our timeseries is fitted to our data having good knowledge of the conditions we are trying to predict. Its limited structure makes it more reliable for mid to short term, and less to long term planning-in any case its accuracy is high. Its adhoc formula for predicting energy demand using 20 years data in timeseries form is:

$$y\ (T) = T\ (t) + S(t)C(t) + R\ (t),$$

where,

- T=long-term trend,
- S=seasonality/cyclical trend,
- R=random variance.

Solving the above model using the 20 years data, we result to energy demand as it is presented to table 39. Solution is based on two transition scenarios, the moderate and the optimistic and the outputs forecasted are listed below.

Table 39. Two forecasting demand scenarios, moderate and optimistic.

Year / scenario	Moderate scenario GWh - Greece	Moderate scenario GWh - REMTH	Optimistic scenario GWh - Greece	Optimistic scenario GWh - REMTH
2020	51.200	2.726	53.870	2.960
2025	54.000	2.970	60.850	3.350
2030	60.730	3.340	66.160	3.650
2035	63.910	3.500	70.120	3.860
2040	66.200	3.640	73.150	4.000
2045	69.650	3.830	75.780	4.200
2050	73.000	4.000	78.000	4.300

Source: Energy Regulation Authority report 2020-NPEC report 2020-elaboration, compilation and adaptation by author.

The above forecasting demands can help us to cost more precise the projected activities for a cost effective transition in REMTH along with the total installed power in Greek/ REMTH ESs . The table 40 summarizes the existing power generation capacity by technology:

Table 40. Existed situation of ES by power production technology (reference year 2021).

Power production technology	Power in MW	Percentage %	Electricity in GWh	Percentage %
Thermal stations	9.319,3	44,3	28.491	54,20
Hydro stations MW/GWh	3.170,7	15,1	9.603	18,19
RES and CEHHP	8.562,1	52,6	14.473	27,61
Total	21.052,0	100,00	52.567	100,00
Information for RES				
Wind turbines	4.564	50,5	7.844,4	54,20
Ph/V	3.469	42,4	5.441,8	37,60
CEHHP	205	1,7	492,0	3,40
Other RES	324	5,4	694,8	4,80
Total RES	8.562	100,0	14.473	100,00

Source: Energy Regulation Authority report 2020-NPEC report 2020-elaboration, compilation, and adaptation by author

The next figure shows the result of our model about the energy demand by sector after 2020 till 2050: Industry-Tourism, Trade, Services-Households-Transportation: each line is equal to 200 metric. **Ktoe**

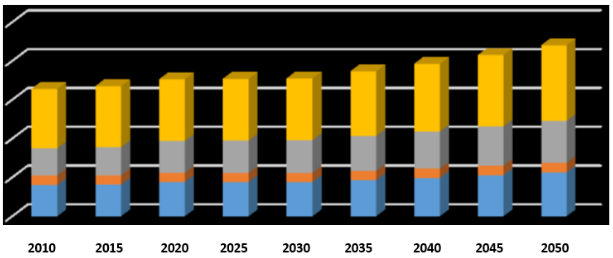


Fig. 13. Energy demand by fuel in REMTH between 2010-2050.

5.2. The CEC-87 model as tool supporting energy planning and measuring the determinants of energy supply

5.2.1 Theoretical analysis of CEC-87 model predicting electricity production

Along with the energy forecasting demand, equal useful is the forecasting of energy production and load by technology. Many factors can maximize the precise of prediction accuracy. Since prediction accuracy offers many benefits to all stakeholders.it is a significant issue and various models deal with it. One of among them is the "California Energy Commission model - CEC-87" and for this we will present it somewhat in details. Its central philosophy, beyond forecasting future production and technologies developments, is either to minimize the CAPEX/OPEX costs of ESs, or to maximize benefits for all stakeholders involved in an ES [47a]. The mathematical formula can take two basic objective linear function forms:

$\mathrm{m}inf(x) = \sum_{j=1}^{n} c_j x_j \ \rightarrow \ x\, E\, R^n$: under a sum of normal limitations,

or

$\max f(x) = \sum_{j=1}^{n} c_j x_j \ \rightarrow x\, E\, R^n$: under a sum of conditional limitations.

The above two functions are in force only when m < n, otherwise the solution of functions refers to a system having m equations with n unknowns. The combination of above functions and after some assumptions and adaptations regarding the factors influencing an ES-energy mix by technology, production variability, flexibility of ES- take the basic formula:

$$C\_dsp + C\_c \leq MC - E(P - MC)\ ((T - MC + \frac{C_{dsp}/(1-F_r)}{T-E(P-MC)})(1)$$

where C_{dsp} : The cost of DNO per MWh, that is the average cost of ES. MC : The Marginal Opportunity Cost of new energy providers entering to the ES. C_c: The direct average cost for energy end-users belonging to a spatial ES in monetary units per saved KWh. E: The elasticity of electricity supply/demand in terms of price, is equal to: $-\frac{\frac{dQ}{Q}}{\frac{dT}{T}}$ where Q is the energy supply or demand quantity and T is the unique price. For Greece, the price of E is equal to 7. F_r: The fraction of Free-Riders energy consumers to all ones adopting the new developments in ES imposed by DNO. Free - riders are consumers who adopt the terms proposed by the DNO after the penetration of new energy providers, mainly RES owners.

From above we should tell that the penetration rate $\boldsymbol{\delta(t)}$ of energy offered by new electricity suppliers in a certain market, or ES can be described well by the equation:

$$d(t) = \frac{1+P}{(1+1/(P)e^{RV})} - P \tag{2}$$

Where $d(t)$ = energy providers % of total ones in an ES or energy market for the year t. P=initial market parameter index that is critically selected based on the knowledge of local factors and information affecting the energy market/ES and take values from 0,005-0,3. R=the Diffusion Rate Parameter that is a measure of the energy penetration rate in the market/ES and it is depended by the investments in promotions actions of new energy providers aiming to gain a share into an existed market. Lawrence-Lawton suggests value 0,5 for household consumers and 0,66 for commercial and industrial consumers and end-users. V=current year t + maturity - reference year (an index aiming to differentiate the penetration of new energy providers at different levels of an energy market).

The main disadvantage of the model is that it takes into account the average cost of the new electricity providers entering to ES. DNO of an ES has to assess the new technical/economic conditions of the ES based on their average cost and not to more exact cost per consumer levelized to average cost [47a]. This maybe allows energy policy-makers to make accurate estimation of the whole soundness of an ES but gives no indication whether it is in the best interest of investors to invest further in new energy sources into the existed ES in order it to operate at optimal point. It is logical that, as new providers wish to enter to a certain energy market, the model described by (1) has to be improved/adapted by the DNO to every new different energy conditions with rather higher degree of entropy, stochasticity, and uncertainty in order to be able to manage them better, leading the ES to a new well-balanced point, eg energy supply/demand conditions to be the optimal for all stakeholders.

While additional RES providers entering gradually into ES, they cost more since their marginal cost increase, because new power of RES undergo to many extra charges. But, it has to be noted that, within the spatial forecasting framework, the marginal cost of new RES providers is given(FIT/FIP) and it facilitates the forecasting and ES's simulation process during the short, mid, long-term planning. Based on the above, it is better to compare the overtime marginal cost of an ES rather than its average cost, because the latter assessment is less reliable. The marginal cost of an ES is denoted as $\boldsymbol{C_{dsp}}$ and, in order to be able to estimate it, the achieved penetration of new RES providers must be estimated at every moment, eg the equation (1) has to be calculated successively in every planning period n.

During the energy planning period, the overall penetration rate is:

$$\Delta(n) = \delta_{new}\ (1) * \big(1 - \Delta(n-1)\big) + \Delta(n-1) \tag{3}$$

and therefore

$$\Delta(n) = \delta_{new}\ (1) + \ (1 - \ \delta_{new}) * \Delta(n-1)$$

where index δ_{new} means that, in each period n the factor P of equation (1) gets a new price $P \ = \ \Delta\ (n-1)$.

Equations (1) and (2) consist of the first adaptation/improvement in the initial dynamic **CEC-87** model for forecasting production and assessing the impact of penetration on new RES providers. Now consumers have more options to choose their power provider. The previous offer the following advantages to upgrading forecasting model CEC-87 used:

- Supports for more precise estimation for each period separately, when new RES providers entering to ES, despite the higher stochasticity/variability of the ES. This leads to the necessity of estimation the new marginal cost of the ES as whole, emerged due to enter new RES providers, who change the standard features of ES. Of course, the new energy mixes in every dt time create more complexity/variability making hard the prediction .
- Shows soon the operational optimization of the ES at the beginning of each period **t** with 1-year horizon instead of 10-year, thus prediction accuracy is increased.
- Simulates better the changes occurring on the energy markets during planning process by DNO's. If it is predicted that after a 4th year of initial planning there will be a crucial change in the energy markets for plausible reasons, changing of LNG prices, degree of openness of energy markets, promotion means used by new energy providers. In other words, the model is flexible and able to manage and simulate all changes making the appropriate modification of the R.
- Has a dynamic character since it uses each time of period the results of the previous one, so that it simplifies calculations, without to use very complex non - linear

equations, and transfers the prices of ES situation to the next one.

From the above is resulted that, the significance of the R in the optimal operation of an ES is obvious and well-understandable. Features like, the coherent of society and the information channels regarding their ability to inform energy end-users have impacted the new providers penetration speed. So the parameter R can be written:

$$\mathrm{R} = \mathrm{R}\,(\mathrm{C}, \mathrm{r1}, \mathrm{r2}, \ldots.\mathrm{rk}, \ldots.)$$

where C: is the total cost (TC) of new energy providers and $\mathrm{r_i}$: is all other factors affecting parameter R.

Total cost TC is in € and can be written:

$$\mathrm{C} = \mathrm{K_t}\,\delta\,\mathrm{M} + \mathrm{CPROM},$$

where $\mathrm{K_t}$: the technical cost/used adopting the conditions considered by upgrading model. δ : the % of the total energy share market that has adopted the criteria put by the DNO’s. M : the size /potential of the energy market occupied by new providers in the long run, and it depends on its economic attractiveness. CPROM: the cost of promotional activities by new energy providers aiming to gain greater shares of total end-users market from existed providers of the ES under study.

The problem raised by the step-by step implementation of model and refers to whether it can reduce the marginal cost of the ES as a whole, due to new entered providers- mainly RES ones. So the calculation of new total cost of ES takes the form of:

$$\mathrm{C_{dsp}} = \frac{\mathrm{Dc_{PROM}}}{\mathrm{Ds}}$$

where S: is the saved KWh’s by the optimal operation of the ES.

So, our model optimizes the cost-effectiveness operation of ES for any time of period planning, based on the criteria pre-set by energy planners and it takes the form:

$$S = a * \delta * M,$$

where:

a: is energy saved annually by a single end-user.

According to previous, we can formulate the next equations able to calculate the new marginal cost of ES:

$$\frac{d\delta}{\mathrm{dS}} = \frac{1}{\mathrm{aM}}$$

and

$$\mathrm{C_{dsp}} = \frac{1}{\mathrm{aM}} \cdot \frac{\mathrm{dC_{PROM}}}{\mathrm{d}\delta} \rightarrow \mathrm{C_{dsp}} = \frac{1}{\frac{\mathrm{Dr}}{\mathrm{dC_{PROM}}}} \cdot \frac{1+\mathrm{P}}{\mathrm{Amv(P+\delta)(1-\delta)}} \qquad (4)$$

The crucial question lies in the determination of the R of equation (4) and, in particular, its first derivative regarding C_{PROM}. The marginal operating cost of new RES suppliers entering to ES is given by the type:

$$F_r = d^R / d^{R(C)}$$

and the marginal promotional cost to gain existed end-users by the equation:

$$C_c = \frac{(1-\varepsilon)\cdot K}{a} \cdot (1 - F_r)$$

The estimation of the impact of promotional activities made by new energy providers for entering into the ES is analyzed to the next.

Let I is the extra share % of the market earned by the new energy providers because of their cost-effective promotional actions in existing energy market. By applying the dynamic penetration equation (2) resulted the new equation:

$$\delta_{new}^{R(C)}\,(1) = \delta_{new}^{R}\,(1) + I \cdot [1 - \delta_{new}^{R}\,(1)] \qquad (5)$$

where the exponent R in δ_{new} means that the achieving penetration rate is independent of the average cost $\mathrm{C_{PROM}}$ of new providers and depends exclusively on the margins given by the DNO. Therefore, from equations (1)-(5), we result to the next equation.

$$R(C_{PROM}) = \ln\left\langle \frac{1}{P} \cdot \frac{\delta_{new}^{R}\,(1) + \frac{I+P}{1-I}}{1 - \delta_{new}^{R}\,(1)} \right\rangle \qquad (6)$$

The exact price of the additional market share I gained by new providers, depends primarily by factors similar to those affecting the R. These factors are extremely stochastic for obvious reasons-unstable energy production of RES, production failures, etc and therefore, are very difficult to be calculated by the equation (6). The mean cost of new RES providers is a critical factor influencing the R-their marginal cost is almost zero. Therefore, it can be taken the form:

$$I = I\,(C_{PROM}, r_1, r_2, \ldots, r_k, \ldots) \qquad (7)$$

where $\mathrm{C_{PROM}}$ is the operational cost of new energy RES providers.

From the above equations (5), (6), (7) we result to equation:

$$\frac{dR}{dC_{PROM}} = 0.05 \cdot v \cdot \frac{1+k}{k} \cdot \frac{1+P1}{(1-I)^2} \cdot \frac{1}{\delta_{new}^{R}\,(1) + \frac{I+P}{1-I}} \cdot \frac{e^{-\nu C_{PROM}}}{\left(1 + \frac{1}{k} e^{-\nu C_{PROM}}\right)^2} \qquad (8)$$

that can calculate the first derivative $\frac{\boldsymbol{d_R}}{\boldsymbol{dC_{prom}}}$ representing the simulation of dynamic model that finally gives the equation formula **(8)** able to address every question regarding the forecasting supply/demand conditions of ES.

The above equation within the framework of short, mid and long-term energy planning made by DNO’s, can define the best point of the existed ES where the total benefits are maximized and mean and marginal costs take the minimum price, despite the entering into it new energy providers changing the balance point of the whole ES.

5.2.2 Implementation of CEC-87 model for predicting power production in Greece/REMTH.

Energy production is a primary concern for Greek society, as electricity is now a critical driver in the proper functioning of the economy. In recent decades, electricity consumption has increased rapidly, an increase that goes hand in hand with the general improvement of living standards. Due to the fact that electricity cannot be stored but must be consumed immediately, at any given time many production units must be operating, which are necessary to meet the total power demand. Since, the large thermal production units present many operational and technical failures, it is necessary to plan their operation in advance. The factors impact the power production/load are many, among them some cannot predict easily due to their variability/stochasticity: climatic, weather, and random and others are more predictable: Population (POP), Number of households (HOUS), Economic activity by sector, = Agriculture/Industry/Construction/Tourism (ECACTIV), International fuel prices (PRIFUEL), GHG emission allowance prices (EMIS), Development of electricity and NG infrastructure (ENGINFRA), Evolution of investment costs of energy technologies (COINV), and Technology potential (RESDYN. All data used come from official databanks, were unstructured and were formed as well-structured timeseries for the period 1998-2018 and introduced to CEC-87 model (8) [17], [21]. The CAC-87 is a non- linear, sigmoid function formed: $F(S) = \frac{1}{(1+e^{a.S})}$. The structured data transferred between its hubs, and we run them in Matlab environment. Each hub in the model receives data from timeseries, modified according to the model's requirements. The output of each hub could be 0 or 1, depending on whether the sum $\Sigma x_i \, w_i$ is greater/smaller than the threshold value. Like hubs weights, the threshold value is a real number that is a parameter of the hub. The algebraic equation (8) is the key [47a]:

$$\frac{dR}{dC_{PROM}} = 0.05 \cdot v \cdot \frac{1+k}{k} \cdot \frac{1+P1}{(1-I)^2} \cdot \frac{1}{\delta^R_{new}\,(1)+\frac{I+P}{1-I}} \cdot \frac{e^{-\nu C_{PROM}}}{\left(1+\frac{1}{k}\,e^{-\nu C_{PROM}}\right)^2} \quad (8)$$

Normalizing the data formed as timeseries before entering them in computational process Matlab (according to CAC-87 model formula 8) and running it we took the next results for REMTH in tabular form.

Table 41. Results of running model (8).

Power Source-Results/year	Production in MWh 2030	Demand in MWh 2030	Production in MWh 2040	Demand in MWh 2040	Production in MWh 2050	Demand in MWh 2050
NG	4.300,0	-------------	5.400,0	-------------	1.600,0	-------------
Hydro	1.580,0	-------------	2.000,0	-------------	2.200,0	-------------
P/V	1.200,0	-------------	1.850,0	-------------	5.500,0	-------------
W/T	1.350,0	-------------	2.200,0	-------------	6.300,0	-------------
Other RES	220,0	-------------	500,0	-------------	2.000,0	-------------
Total REMTH	8.650,0	3.870.0	9.400,0	4.750	12.000,0	5.600,0
Total Greece	62.540,0	60.730,0	69.870,0	66.200,0	76.000,0	73.000
REMTH/Greece	13,8	6,4	13,5	7,2	15,8	7,7

Continuing analysis for this issue we give a picture about factors influencing power production and load as they result by the model and a diagram regarding the accuracy of model checking the case of existing autocorrelation among variables influencing power production/load.

From the diagram below, fig. 14., results the case of minimal autocorrelation tending to zero-n our case is 0.0003 and it lies within the **5%** confidence interval.

Table 42. Estimating the % of contribution of factors influencing the power production-load.

Factors impact on power production/load	Contribution by % in Country's level	Contribution by % in REMTH's level
Population evolution-demographic pyramid	4,8	6,1
Number of households	6,4	6,4
Οικονομική δραστηριότητα	51,2	55,1
GDP changes	8,0	9,0
Agriculture	7,6	11,2
Industry	20,5	21,1
Constructions	7,3	7,6
Tourism	7,8	6,2
Energy market indices	37,6	32,4
Fuel prices	6,5	6,5
Prices of GHG/emission trade conditions	8,1	5,2
Evolution of investment costs of energy technologies	9,8	9,8
Potential of RES technologies	3,7	2,8
Development of electricity infrastructure	7,2	5,6
Development of NG infrastructure	3,2	2,5
Total	100,0	100,00
Coefficient of determination R^2	0,92	0,93
Autocorrelation within the 5% confidence	0,0003	0,0003
Mean deviation from the power adequacy point	2,5% -14,2%	2,4% -14,0%
Standard deviation	8,4	8,3

Source: Dergiades et al. (2013) - significand calculations, adaptations, and compilations by author.

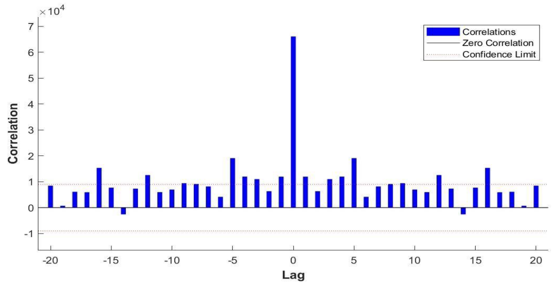


Fig. 14. Minimal autocorrelation within the 5% confidence.

Normalizing our model for cointegration function of variables giving it the form of equation (9) that is capable to estimate the energy supply/demand:

$$\mathrm{ELECTR} = 0{,}45 \cdot \mathrm{POP} + 0{,}23 \cdot \mathrm{HOUS} + 0{,}31 \cdot \mathrm{GDP} + 0{,}37 \cdot \mathrm{ECACTIV} - 0{,}25 \cdot \mathrm{PRIFUEL} + 0{,}31 \cdot \mathrm{EMIS} + 0{,}29 \cdot \mathrm{COINV} + 0{,}67 \cdot \mathrm{RESDYN} + 045 \cdot \mathrm{ENGINFRA} + 5{,}2 + \mathrm{Z} \tag{9}$$

The equation (9) helps us to choose the best solution that is given by the following equation(10):

$$\Delta \ln(ELECTR) = \alpha_0 + \sum_{t=1}^{k} \alpha_1 \Delta \ln(ELECTR_{t-1}) + \sum_{i=0}^{i} \alpha_2 \Delta \ln(POP_{t-1}) + \sum_{i=0}^{m} \alpha_3 \Delta \ln(HOUS_{t-1}) + \sum_{i=0}^{n} \alpha_4 \Delta \ln(ACACTIV_{t-1}) + \sum_{i=0}^{O} \alpha_5 \Delta \ln(PRIFUEL_{t-1}) + \sum_{i=0}^{p} \alpha_6 \Delta \ln(EMIS_{t-1}) + \sum_{i=0}^{q} \alpha_7 \Delta \ln(COINV_{t-1}) + \sum_{i=0}^{r} \alpha_8 \Delta \ln(RESDYN_{t-1}) + \sum_{i=0}^{s} \alpha_9 \Delta \ln(ENGINFRA_{t-1}) + \gamma\left[\ln ELECTR_{t-1} - 0{,}45POP_{t-1} + 0{,}23HOUS_{t-1} + 0{,}31GDP_{t-1} + 0{,}37ECACTIV_{t-1} - 0{,}25PRIFUE_{t-1}L + 0{,}31EMIS_{(t-1)} + 0{,}29COINV_{t-1} + 0{,}67RESDYN_{t-1} + 045ENGINFRA_{t-1} - 23{,}2\right] \tag{10}$$

Running the above model-equation we take the results presented to the table 43.

Below we present in tabular form all the diagnostic tests and indicators used to test and evaluate the B-ANN mode

Table 43. The elasticities of eight factors in relation to energy demand for long-term planning.

Variable or factor*	Elasticity OF ELECTR	Elasticity of PRIFUEL
ELECTR	***0,22b (1.88)	X
GDP	0,96(1,87)	0,84(1,82)
ECACTIV	0,82a (3,02)	0,62b (2,34)
EMIS	-0,12b (2,23)	0,02c (1,75)
PRIFUEL	X	0,56a (3,79)
COINV	0,81a (3.02)	0,61b (2,33)
RESDYN	-0,006 (-0,11)	0,006 (0,32)
ENGINFRA	-0,11b (1,96)	0,07b (2,66)
C=STABLE TERM **	-0,01(-1,42)	0,006 (0,49)

* This result satisfies the principle of Le Chatelier, according to which "long-term elasticities exceed the corresponding short-term". This means that energy-users adapt their economic behavior more quickly to changes in interpretive variables in the long run than in the short run [83], [88].

** In the above, the lag-order **k, l, m, n, o, p,** was selected so that the residues to be globular white noise. The relative lag-order was initially set equal to **1** with annual data and then, by deleting the non-statistically important parameters, **ECM** emerged normally. This estimate is quite reasonable as in the electricity forecasting production/demand models, so the production/demand elasticity to GDP is set around **0,98-1,0.** The use along with our model the translog one allow us to estimate the substitution elasticities between electricity and NG inputs, but due to lack of such necessary data it was not feasible.

*** The numbers in parentheses are values of the **t-student** statistic, indicating statistical significance at levels of 0,01-0,05-0,10 respectively

Table 44. Diagnostic tests and indicators for two factors, ELECTR and EMIS**.

Test of diagnosis*	Δ(ELECTR)	Δ(EMIS)
Regression R^2	0,74	0,61
Corrected Regression $\overline{R^2}$	0,64	0,45
F- statistic	7,35 (0,00)	3,25(0,02)
Durbin-Watson	2,11	1,69
Breusch-Godfrey LM Test	0,67 (0,43)	1,063(0,34)
LM (8)=n R^2	1,56 (0,28)	0,44 (0,88)
White test or homoskedasticity	0,49(0,90)	0,48(0,92)
Jerque- Bera test	4,19(0,14)	1,83(0,42)
ARCH test	0,67(0,44)	2,01(0,19)
ARCH LM test (8)	0,50(0,80	1,41(0,32)

* The numbers in parentheses are values of the t-student, indicating statistical significance at levels of 0.01-0.05-0.10 respectively.

** The diagnostic method used estimates with good satisfactory the values of tests. since the ECM model does not violate the basic assumptions of our basic forecasting model, eg the existence of homoscedasticity and lack of autocorrelation. The table below summarize the independent variables/ determinants of directly encouraging/discouraging power supply/ demand and indirectly GHG emissions.

Table 45. Summarizing independent factors/variables encouraging/discouraging power production/ demand and influencing emissions.

Encouraging power production/demand and discouraging emissions	Discouraging power production/ demand and encouraging emissions
Increase of GDP and economic activity by sector	Stagflation economic conditions
Evolution of the population-demography	Decrease of population
Low CAPEX of new energy technologies with low GHG emissions	High CAPEX of new energy technologies with low GHG emissions
Low OPEX of new energy technologies with low GHG emissions	High OPEX of new energy technologies with low GHG emissions
The physical potential in solar and wind and their carrying capacity	Lack of physical potential in solar and wind due to ground relief

Encouraging power production/demand and discouraging emissions	**Discouraging power production/ demand and encouraging emissions**
The optimal highest share of RES in energy mix	The minimum share of RES in energy mix
High energy savings in buildings, transport, and industries	Low energy savings in buildings, transport, and industries
High energy efficient in buildings, transport, and industries	Low energy efficient in buildings, transport, and industries
Smart grids and telemetering for all end-users	Expensive grids and metering systems
Degree of flexibility of ES to respond quickly to changed/peak demand	Lack of flexibility in ES
The full competitive price of KWh and NG/M3	High price of KWh and NG/M3
Degree of interconnection of Greek/REMTH ES	Least interconnection of Greek/REMTH ES

Source: Author's final views coming from many sources elaborated and structured by him

Table 46 estimates in a qualitative basis the independent factors/variables encouraging/ discouraging power production/ demand and influencing emissions.

In conclusion and continuing the modeling analysis of this part of work, we note:

1. All forecasting scenarios done by NPEC with its own model predicts much higher electricity production/load/demand than our forecasts. The mean deviation from the power adequacy studies ranges from 14,2% to 25,0%.
2. In order to test the existence of Unit Roots and Stationary of timeseries, we tested both, Dickey-Fuller and Philips-Perron Augmented and KPSS (Kwiatkowski-Philips-Schmidt-Shin).
3. According to Dickey-Fuller, Philips-Perron and KPSS tests, they were calculated through the general VAR model. With VAR we also estimated the long-term elasticity of power production/demand and the optimal number of lags that were incorporated in model in order to eliminate the autocorrelation problem and it was estimated with lag -length **p = 1.**
4. The test results show that both, statistical criteria, maximum eigenvalue check and trace statistics used for the existence of a cointegration vector in the VAR, providing clear indications of the existence of cointegration.
5. We normalized our model for cointegration of variables giving it the form of an equation with 9 independent variables, capable to estimate the energy supply/demand.
6. The effect of electricity price (RPELEC) on electricity production/demand was estimated at a level lower than the **1,0** and with a negative sign **(-0.25**), while the cross-elasticity (RESDYN) is positive (**0,67**), indicating the existence of substitutability between the two alternative energy sources, NG and net power production/load without huge economic losses at this time being.
7. Knowing the pre-estimated power elasticities by Greek National Accounts, we estimated through VAR the Error Correction Model -ECM the energy elasticity separately by type of technology and check them if they diverged a lot from all ready pre-estimated elasticities .
8. After all previous, our next step was to use statistical tools to test and evaluate methods against Reasonable Alternative Solutions, or scenarios analysis. Evaluation was done by 4 steps, Testing Assumptions, Testing Data, Replicating Outputs, and Assessing Outputs. Since our forecasting model used to predict at same time the energy production/demand and the independent variables/factors influencing them in long-term period of 30 years, we tested our model in situations resembling the actual energy situation in REMTH as they are known..
9. Yet, the model shows that the max power generation capacity should be proportional to the max aggregate demand and not to the sum of the max individual demand and exactly vice-versa for production.
10. The outage frequency and time is a very important stochastic variable in REMTH's ES causing consequences to every power producer and user. For example, since now the energy storage technology is not cost-effective, large amount of energy of RES is lost but it is not estimated by our model, due to lack of such overtime adhoc data. According to studies done by RAE, PPC, IENE, this drawback has an extra cost equals to 5,6% of REMTH's ES OPEX (RAE, PPC, Sanstad Alan at al, 2020- US Department of Energy)
11. Since in short-run, elasticity of energy prices is extremely small-less 0,076, the balancing of supply/demand requires power facilities that will be able to be adapted to the rapid changes in "on/off peak" conditions-best flexibility, meaning a gap in GWh reaching in 67,3% and 56,9% in Greece and REMTH 's ES's. Today the solution is the most cost-intensive industries to stop operating[106]. When demand is off-peak, only the most efficient units are likely to be competitive and all others will be shut down temporarily and vice-versa for on peak fact. Less efficient units supply power only at on-peak condition, about 387,3 h/year [106]. As the power production mix changes, the cost of electricity changes over the day with a lag of 15 minutes in relation to power supply moment.
12. Given the complexity of Greek/REMTH energy markets due to multi-laws regime ruling the ES, it is needed an additional cost 12,3% in order ES to be reliable at least 90% for uninterrupted power supply [82], [106].

Table 46. Determinants' degree encouraging/discouraging power demand and GHG emissions X=Least, XX=Slightly moderate, XXX=Moderate, XXXX=Great XXXXX=Very great.

Encouraging power demand and discouraging GHG emissions	**Encouraging**	**Discouraging**
Increase of GDP and economic activity by sector	XXXXX	X
Evolution of the population-demography	XX	XX
Low CAPEX of new energy technologies with low GHG emissions	X	XXXX
Low OPEX of new energy technologies with low GHG emissions	XX	XXXXX
The physical potential in solar and wind and their carrying capacity	XXXXX	X
The optimal highest share of RES in energy mix	XXXXX	X
High energy savings in buildings, transport, and industries	XXXXX	X

Encouraging power demand and discouraging GHG emissions	Encouraging	Discouraging
High energy efficient in buildings, transport, and industries	XXXXX	XX
Smart grids and telemetering for all end-users	XXXXX	XX
Degree of flexibility of ES to respond quickly to changed/peak demand	XXXXX	XXX
The full competitive price of KWh and NG/M3	XXXXX	XXXX
Degree of interconnection of Greek/REMTH ES	X	XXX

Source : Brent RJ (2009) , Stathakis, E. et al. (2015) and elaboration adaptation and compilation in regional basis by author.

Remarks:
The CEC-87 model being a statistical predictive one, operates under certain conditions:

-The coefficient of determination **R^2** shows whether the overall performance of the model is satisfactory. Running model we found that **R^2=0.92,** concluding that the training is satisfactory, as **R^2** is collectively calculated at high levels.

-For the evaluation of the reliability of **CEC-87,** the visual representation of the dispersion with the estimated timeseries is also important. Usually, real timeseries contain white noise, incorrect values, random event logs and other data alterations and CEC-87 model is able to recognize the real timeseries features and ignore random deviations, cyclicity, seasonality, stationarity.

-An important role in the efficiency of CEC-87 is played by the autocorrelation of the errors that occur and must be random and not repeated periodically in subsequent steps of the timeseries. If this is not the case, then the conclusion is that the timeseries is not properly adapted to the periodicity, or that it reproduces patterns that may have been caused by white noise or by repeated random deviations.

5.2.3. Flexibility Services (FS), power sufficiency and performance of REMTH's ES as parameters involved in transition process

REMTH is the region being in the starting point of switching its ES from concentrated system based on large power units and conventional transmission lines to a smart, digitized, networked and 2-way flows one. Today it enjoys in Greece the highest share of variable RES, 33,5%, with more than 45% of electricity demand being covered by wind /solar power and the rest by NG and Hydro 2 units. Balancing RES variability from flexible sources will play a key role in the new reality of its ES. In the context of a drastic reduction of the carbon footprint of the electricity sector in the perspective of 2050, RES will approach 90-95% of total electricity generation. As a result, a variety of flexibility services need to be developed. Flexibility is the critical new service for REMTH's ES in order to avoid load outages. To this context, it is needed to analyze some technical indices related to variability, uncertainty, power sufficiency flexibility, performance expressed by CF of REMTH's ES in order to realize the technoeconomic potentialities of it and how regional energy authorities should cope with the problems arising by it due to great share of RES in its energy mix. Flexibility of ES power generation means that its ES can respond to both ,predictable and unpredictable changes in power production and demand in a way that meets reliability standards while avoiding outages. The ability of REMTH's ES to cope with volatility depends on the availability of appropriate means of energy production, storage and demand adjustment. Not all means of production are suitable for providing best flexibility, especially when the variability is high due to large share of RES, greater than 20% in REMTH. There are 3 types of volatility in REMTH's ES, the unpredictable changes in very short periods of time, the predictable daily volatility in hours due to solar and wind energy stochasticity in few days prediction due to extreme events, which requires large cost-intensive reserve system. The 3 types of volatility and induced uncertainty, cause the need for reliable reserves and flexibility services. Hourly variability requires rotating power reserve and ancillary services that can handle it effectively. However, they will need to increase reserve power, as the RES's increase their share. Daily variability requires energy plants that are scheduled to operate/shutdown on a standard hourly basis. Variability and uncertainty have different characteristics. Both cause the need for reserves and flexibility services. However, variability is predictable more than 65%, while uncertainty is, by definition, stochastic. Variability often has a known periodicity, while uncertainty does not. It is statistically known that wind systems increases more uncertainty, while P/Vs increase more variability. The measurement of flexibility of conventional CCGT unit refers to load ups/downs, its minimum operating power, the synchronization and shutdown time and automatic reserve capabilities.

With measuring the indirect flexibility of Nestos Hydro unit's storage system, and adjusting the demand, REMTH's regulator can reduce CCGT unit ups/downs and cope better with peak load, reducing load variability. Adapting load flows to grids interconnections, where it is included and ancillary services, can provide better flexibility services under certain conditions. The demand adjustment in REMTH, thanks to 300MW storage capacity of Nestos Hydro plant, is very useful for dealing with indirectly flexibility because it allows the daily load shifting, but it cannot provide flexibility for long load increase. With the increase of RES more than> 20%, the ups/downs rate requirements exceed those for monitoring the fluctuation of the demand load. Today, in REMTH, the net demand load minus RES variables tends to range much more and faster than in the past, from 14,4% to 21,5%. The third type of variability is addressed only through long-term reserve systems- replacement reserve systems. The technical means that can provide flexibility have different possibilities regarding the three variability classes in REMTH's ES. The CCGT of Komotini 486 MW, is suitable to provide flexibility for short-term variability, as it is under automatic production control and suitable for providing long-term flexibility, in particular for managing the daily fluctuation of solar and wind energy over several days. The CCGT unit has moderate rates of load ups/downs due to its age. Since it is going to be installed 2 new technology CCGT units 1520 MW till 2024, RAE has to re-schedule the operation program of 3 CCGT units, regarding their effective hourly start/ shutdown, so that they are available to provide long hours of flexibility services. During peak hours the 3 units will determine the margin price of MWh, so they have a purely commercial operation facilitating ES providing flexibility services. The Nestos hydro unit 485 MW with storage capacity of 300 MW is suitable for reducing peak loads and facilitates meeting the requirements of long hours flexibility. Since there is often a shortage of water, it cannot systematically provide load increasing services, but can cover short-term variability. REMTH's ES power adequacy has 3 dimensions, power adequacy for Ramping Service Provision 1-3 hours, programming to avoid the risk of RES cuts during minimum load and covering 100% peak demand services. It is almost certain that the provision of flexible sufficient power in REMTH to be based solely on market mechanisms involved great risk because the share of RES in power mix is high meaning, and high variability. Wholesale market mechanisms should: reduce the degree of use of NG units. b) be created illegal competition because of the provision of flexibility services from existed CCGT unit can be exploited free of charge by the other 2 new competitors who do not provide such service while they also need it-free riding case, c) the 3 CCGT units will be strained when they provide intensive flexibility service while there is no way to recover the extra maintenance costs 100% from the market, d) simulations and related economic analyzes show that investments in storage systems and demand adjustment will not be made if financed solely by the variability of system's marginal prices, because this variability decreases with the expansion of RES. The table below gives an indirectly index of efficient of REMTH's ES through the Capacity Factor of its power production units. [82], [101], [116], [121].

Table 47. CF and nameplate/actual power production in REMTH as average value for 2015-2019. (Facilitating energy storage to allow high penetration of intermittent Renewable Energy)

Power generation technology	**Nameplate production MWh**	**Capacity Factor %**	**Actual production GWh**
P/V parks 485 MW	4.000.000	18,7	750,0
W/T parks 501 MW	3.000.000	28,5	870,0
Hydroelectric power plant 486 MW	2.750.000	40,0	1.250,0
Other RES-No remarkable	0,000	0,0	0,000
Total RES	9.750.000	-----------	2.870,0
*Flexibility index of CCGT unit -how it increases flexibility for every 5% increase of RES share	8,8	-----------	146,2
*Flexibility index of hydro unit -how it increases flexibility for every 5% increase of RES share	4,6	-----------	76,4
Ramping Service Provision in hours/yearly	245	-----------	-----------
Ramping Availability Provision %	87,3	-----------	-----------

Source :RAE reports 2010-2020, PPC reports 2010-2020 , IENE reports 2010-2020-many re-calculations and adaptations by author

*They show the speed to which the supply respond to demand changes when RES percent is greater than 20%

6. Part Two: Implementing The Proposed \Transition Plan In Remth. Sub-Part A: Methodology For Selection The Best Energy Mix By Close The Marginal Units

6.1. Specifying the methodology and steps for optimization of transition

Energy transition means that the today REMTH's ES will have to switch from concentrated structure based on large size power units and conventional transmission lines to a smart, digitized, networked and 2-way flows one producing almost zero GHG emissions. In practice mean various actions and projects to be implemented by central and regional governments. To this work we essentially answer to emerged questions, how regional governance should be effectively involved in transition and what does it mean in practice. So, being the transition a complex issue, needs complex methodological tools. It means our approach is a multi-method in order to be able to deal with all technoeconomic factors evolved to energy cycle, production, supplying, transmission, distribution. Such tools will be: a. the max/minimization of energy production function f=(X), X=are all indepented variables, power technologies, capacity factors, marginal and average costs, degree of pollution expressed in CO2/GHG emissions/KWh b. descriptive and inferential statistic and c. Social Cost Benefit Analysis (SCBA). Supplementary tools to above can help us to maximize much more the benefits, selecting the optimal RES technologies and other smart techniques minimizing carbon footprint. Yet, an ES is preferable when it has: the largest share of RES in energy mix, the highest efficiency and saving in every use, and the most competitive prices for all end-users. In this context, it is considered as plausible that in the open Greek/REMTH's energy markets, "the most competitive power units will displace the marginal ones". To the next we present the three key-supplementary tools- and why we chose the certain one, ever under the principles and rules of SCBA[18], [54], [82], [105], [119].

- **Marginal Pollutants of Unit Tool- MPUT**: GHG emissions of marginal producers are considered as unprofitable and the method looks for how/when marginal producers will have to be substituted by new ones, eg new RES. Essentially, through this method, we try to optimize the benefits and minimize the cost of proposed actions for transition step by step: Mathematical form $\mathrm{Polb} = \mathrm{X} * \mathrm{margPol}$.
- **Operation Factor Tool-OFT**: the CF of each power technology and the corresponding percent of marginal units can be substituted are taken into account achieving the best mix. Units with low CF are substituted by those with high CF. A unit with CF <20% is considered to be continuously substituted, while conversely units with CF> 80% will never be substituted. Essentially method is based on SCBA along with an adhoc maximizing function forming: Mathematical form $\mathrm{CF}_{\max} = \mathrm{B}_{\max}$.
- **Often Measuring Tool-OMT**: Based on USA EPA data from a 5-minute recording of emissions from all major units in each region. Yet, based on previous, the units that constantly change their power to be adapted to changes in load are identified and these are considered the marginal units:

  Mathematical form $\mathrm{POW}_{max} = 5 * \mathrm{Pol}_{\min}$.

  To this monograph we will use the OMT one, because it is the simplest in calculations and the data needed are the least ones and available in regional basis after some adaptations and compilations. The table below presents all the necessary data for comparison various indices that will help us to find the marginal power units that will have to be closed soon.

Table 48. Technoeconomic data by power technology useful towards the energy transition roadmap: reference year 2020.

Power technology/ CO2 emissions ton/GWh	Power in MW	Power produced in TWh	Emissions Kgr/ MWh	Capacity Factor CF %	CO2 produced in tons	CAPEX/* MW in €	OPEX/* MW in €	Utility-scale energy tech CF %	LCOE €/MWH
Lignite	2.300	10,42	1.054	18,7	109.828,2	----	-------	17,3	39,9
Coal	10	0,0004	888	22,4	26,3	-----	-------	20,5	37,4
Oil	1.220	4,60	733	30,4	46.870,0	-----	-------	26,8	40,4
NG	6.920	17,30	499	35,8	68.500,8	600	52,2	48,3	55,0
Solar PV	3.131	3,97	85	20,6	22,7	1.250	60,4	19,1	68,3
Wind turbines	3.861	7,28	26	32,3	42,4	1.450	51,4	32,2	58,5
CHIP	100	0,12	2	52,4	23,8	1.230	48.9	42,2	50,3
Hydropower L/S	3.416	4,00	26	31,4	330,8	2.000	42,1	26,8	45,6
Biomass-biofuel	97	0,37	45	58,3	564,5	3.000	35,5	58,8	39,8
Total or weighted average	21.055	48,06	547	32,6	226.209,5	1.678	38,5	42,1	48,5

Source : Cherp A et al. (2008), Goletsis GA (2000). Significand calculations, adaptations, and compilations by author *: there are no costs because new plants don't create the last years.

From the table it is resulted that towards the transition, the order that marginal units will have to be shutdown is: lignite, coal, oil. The above mean that after 2045 in REMTH's energy mix will have to participate only RES and a small percent 5-8% of NG as alert reserve units when very extreme events will happen.

6.2. Assumptions and acceptances of our method and models used

- The data used are based both, on desk research, collected in accordance with the accounting to statistical rules laid down in Directive 2009/28/EC and on field research regarding the degree of acceptance of transition costs and activities by local societies. The latest available data on energy mix, energy demand/consumption, CAPEX/OPEX and GHG emissions refer to year 2020.
- The share of RES in gross energy consumption is identified as a key indicator for measuring progress under the strategic transition project "Europe: the roadmap to 2050".
- Gross domestic energy consumption constitutes the total amount of energy resources used for all purposes.
- Gross final energy consumption is defined as energy consumption by industry, transport, households, services including public services and agriculture.
- Energy statistics available from Eurostat do not distinguish between sustainable and unsustainable RES.
- The share of RES in transport sector is calculated on the basis of energy statistics, according to the methodology described in Directive 2009/28 / EC.
- The share of RES in heating/cooling sector calculated as the final energy consumption by the sector coming from RES.
- The external energy production costs and benefits due to proper come from well-documented public and private databanks and are given to the next table.

Table 49. External costs and benefits of power technologies.

Power technologies/type of external costs	Environmental cost €/MWh	Safety of production transmission cost €/MWh	Benefits of energy cycle * €/MWh
NG	6,9	4,4	3,3
RES-P/V	1,2	0,003	0,08
RES-W/P	1,6	0,004	0,10
Hydropower	5,6	2,4	3,6

Source : Cherp, A. et al. (2008), Goletsis GA (2000) - Significand calculations, adaptations, and compilations by author - *life cycle energy implications of increasing the thermal energy efficiency levels of whatever end-using

- Field research became via a questionnaire delivered to 56 power end-users and energy opinion leaders of REMTH. In sampling we did not follow 100% the rules of statistics because it was very time/money-consumed. The answers were very useful to this work-better documentation of what is consider as prevailing atmosphere and what was acceptable by local societies.
- Conclusively, our approach refers to combination of all methodological tools capable to optimize the transition process: function f(x)=(X), SCBA, descriptive and inferential statistics and OMT three key parts. All such tools we help us to make: a. a generic describing of transition through quantitative/qualitative goals to be achieved in due time b. a course of step by step actions towards the transition roadmap along with to calculate the needed budged to fulfill the specified quantitative/qualitative goals/projects as they defined by economic and forecasting analyses c. finding the proper statistical measures and indices useful to objectifying the qualitative goals d. making a final cost/benefit analysis of transition actions and projects. Descriptive statistics will determine statistical indices useful to our analysis and presentation of findings related to a data set derived from our sample. It will comprise three main categories of

measures, Frequency Distribution, Central Tendency, and Variability that will allow us to present results in a meaningful and understandable way, which, in turn, will help energy decision makers to interpret the results in useful decisions. Regression analysis is a statistical tool for the investigation of relationships between variables. It will help us to forecast the future average power demand/supply, on/off-peak demand, CO2/GHG emissions, necessary capacity of storage systems by technology, saving energy by user, rate of classical vehicles will be replaced by EV's and the needed investment capital. SCBA for a detailed technoeconomic evaluation of transition projects. It has been developed over a long period of time for policy decision-making with a great deal of promise to lead to the right decision. SCBA in energy policy has fundamental flaws in a practice of energy management and environmental protection.

7. Sub-Part B: The Roadmap Towards Energy Transition.

7.1. Introduction to effective and just transition

The EU had set in 2010 energy goals under the name 20-20-20 for climate protection which were implemented by 95% by Greece. In 2020 new goals set by EU under the name "**New Strategy for Energy and Climate-NSEC**" that will have to be carried out gradually till 2050 and are mandatory for EU Member States. These goals aim to improve, the energy performance in all aspects, optimal balance of power demand/supply, 90-95% clear energy produced by RES, higher energy efficiency,/effectiveness by at least 45-50% through adhoc investments in new technologies, energy saving in buildings and industry and electrification of transportation[8], [10], [18], [59]. Optimal balance of power demand/supply could reduce energy losses and transmission cost about 18,5%. Energy efficiency could contribute to cost-effectiveness of ES by 28-33%. Clear power produced by RES will reduce the CO2/GHG emissions by 65-75% comparing to 2005 and 85-95% comparing to 1990, meaning decreasing of indirect cost of power by 34,6%. Energy saving in buildings and industry is the cheapest and cleanest source of energy, since it is energy that does not be produced and it should contribute to climate protection more than 50% - all the other factors are responsible for the rest 50%. And finally, since transportation is responsible for 37,2% to GHG emissions, its electrification will contribute to climate protection by 25%[18], [59]. The national Regulation Energy Authority (RAE) aiming to cope with them, proposes 7 key-actions for the country's energy transition that, after an adaption in regional level, have to be carried out in REMTH.

- Increasing the RES share to the levels of 20 GW from 7,5 GW in 2021. Such a share of RES is equal can meet twice the today on-peak and four times the off-peak demand.
- Promotion of pilot projects in offshore P/V and W/T parks since the onshore areas are limited and the total offshore sunny and wind potential of Greek seas is 289/263 GW and Thracian 13/9 GW. Respectively the today interest by energy investors reaches 0,15/10 GW.
- Promotion the interconnections of the islands with inland network, till 2030 so that to be shut down the today high-cost thermal plants using oil as fuel.
- Strengthening the country's cross border/EU interconnections with the ability to import/export power every moment for optimizing supply/demand points and power mix with the lower marginal cost.
- Promotion power exports so that Greece /REMTH to be done clear power exports by exporting 15% of total energy production till 2050, nullifying the today imports.
- Enhancing the flexibility of the power system by 40%, introducing smart management tools and storage technologies and reducing the marginal cost by 43%. They have to create large-scale storage systems able to yield high flexibility to ES. Today, among the existing storage technologies, pumped-hydro is the dominant in Greece/REMTH, reaching 699/300 MW respectively.
- Promotion of green H2 production by electrolysis, a very promised indirect power storage technology for near future. The green H2 will be used either alone by injecting in the existed NG pipelines, or in mix with NG in various portions %.
- Promotion the best power mix in every region via the combination of RES available, green H2, that will achieve the max positive impacts for the three pillars of real sustainability, environmental, economic, and social. The sustainability criteria for selecting the best mix for REMTH are, according to our research are given to the next table:

Table 50. Sustainability criteria for a real energy transition.

Sustainability criteria for a real energy transition	**Importance %**
Energy sustainable resources availability	26,,5
RES technology availability	20,0
Energy average/off-peak/on-peak demand	18,2
Environmental indicators related to efficiency of RES productivity, land availability, infrastructure	11,2
Economic indicators-energy sources abundance, their cost effectiveness and profitability	11,0
Social indicators, impacts on regional development, new jobs, local added value	10,7
Operational requirements to make the RE initiatives sustainable	2,4

Source: SEEI, IEA adhoc reports 2019, 2020-unofficial field research in a sample of 56 energy users and opinion leaders of REMTH

The next step of NSEC is how the previous 7 proposals can be achieved with the most just and cost effective way, ever in the light of a fair transition for all, without exclusions. The implementation of all above ambitious commitments entails drastic changes not only in the goods/services production, the way we move and consume, but also in the economies of local communities, which have been dependent on fossil fuels for decades. A key role in this successful transition process can play, firstly the strategic planning that went beyond a 4-years electoral cycle, secondly the social dialogue with the participation of all stakeholders at the local level, chambers, trade unions, banks, local businessmen, civil society, academics and, thirdly, the generous financial support and the gradual implementation of the reforms in the long-run able to help the success of the whole project.

According to International Labor Organization-ILO report (2020) 'Skills for a Greener Future', a fair transition towards environmental sustainability will require a new way of thinking and redefining/upgrading workers' skills for reduce-ing the risk of unemployment, poverty, and inequality. In contrast, the WWF and Greenpeace consider as fair transition a "broader project that addresses issues like, environmental justice, human rights, mass participation to environmental movements so that to be transit to a 100% green economy till 2035. In conclusion, the success of the fair transition presupposes a holistic approach and, above all, the cooperation and active participation of stakeholders and local communities, which will be most affected by the forthcoming changes. Only if there is social and political consensus will a fair transition have any hope of a successful implementation [22], [29], [30].

7.2. An outline of Greek institutional, economic, social and environment frame supporting the just transition

Greece, therefore, REMTH after 2016 introduced and implemented gradually all commitments coming from Kyoto and Paris Climate Treaties/Protocols and adopted by EU in order all members to be complied with them. Also, members have introduced from 2019 all directives coming from the adoption the 58 rules of Target Model (TM). So far, Greece adopted 21 rules that really have contribute to further upgrade efficiency and fair competition of its energy markets through greater liberation. Indeed, indices such as marginal cost, flexibility of energy mix, and CO2/GHG/KWh emissions have improved at least 15-20% supporting the demanded more cost- effective transition. REMTH as Greek region, strengthened its regional role in SE Europe as a significant energy hub. Greece /REMTH have implemented, with extremely unfavorable conditions, a large number of useful reforms in their energy sectors. In addition to structural reforms, they have developed a holistic sustainable development strategy aimed at increasing the contribution of energy, to GDP growth by 4% to 6,5% (2021) and to 12,3% till 2050 [NSEC 2020]. A new role in just and effective transition is going to play relative innovations. Innovations can utilize the spatial comparative advantages of the country/REMTH, attracting smart investments ready to exploit such innovations with the highest local added value. Yet, innovations need high skilled human power, good technical infrastructure, and smart financial tools so that to make the certain area Porter's diamond. According to the official estimations the necessary reforms in energy sector for a cost-effective transition will attract investments over € 85 billion for the period 2020-2050, financed by both, private and public resources. The same studies predict a positive impact on development rates equal to 0,6% to GDP/year (IOBE/EIRI study 2020). The most emblematic planned investments are those to, power production by RES, electrification of transports, transformation of grids to smart ones, introduction of smart meters in all end-users of electricity, crossborder ES interconnections, upgrading NG existed units, new energy mixes replacing NG by H2 and RES, upgrading building stock energy efficiency, and promoting technological research for greater performance of RES [6], [17], [18], [98].

In this work, national/regional goals for transition have scheduled for three milestones, 2030, 2040, 2050. The end of each cornerstone decade will have to be led to a new economic production system with, almost zero GHG emissions, min cost of reserve units for cope with flexibility (National Plan for Energy and Climate- NPEC towards 2050 report 2020). The following table lists the key NPEC policy priorities by subject considered necessary to achieve the transition objectives in national/regional levels.

Table 51. Basic priorities of NPEC (The goals cannot be recalculated if some conditions dramatically change).

Type of goal	**GDP share as % of total GDP - have to be increased**	**Energy saving in all end-users**	**Reduction of GHE emissions**
Basic or First	The RES share to reach at least 85% of total energy consumption till 2050	The final energy consumption to reach 25 Mtoe, and 70 GWh till 2050	Emissions in sectors out of emissions trading scheme should be reduced by at least 100 % compared to 2005 and should not exceed 54Mt CO2eq.
Second goals	The share of renewable energy in the gross final consumption of electricity to rise to at least 55%	Primary energy consumption not to exceed 25 Mtoe in the year 2030	Emissions reductions compared to 2005 for the sectors within the emissions trading system, to achieve a dramatic reduction by 2050 compared to the year 2005, and not to exceed 41Mt CO2eq.
Third goals	The share of RES for heating and cooling needs to exceed 30%	To achieve at least 7-7.3 Mtoe of cumulative energy savings during the period 2021-2030	Achieving quantitative targets for reducing national emissions of specific air pollutants
Four goals	The share of RES in the transport sector to exceed 14% according to the relevant EU calculation methodology	To carry out an annual energy renovation of 3% of the total area of the thermal zone of the central public administration buildings until the year 2030	Achievement of climate qualitative goals

Source : Ministry of Environment and Energy-adaptations and compilations by author.

7.3.Describing the horizontal projects for a spatial successful transition

The National Energy Policy Framework-NEPF planned by NPEC for transition is ruled by the corresponding one of the EU. For the best implementation of NEPF an extensive national regulatory framework has been developed by Greek state. This framework is updated over timely, taking into account the results of the ongoing operation, as well as the developments taking place at national, regional, and European level. So far, 21 projects have been implemented in Greece/REMTH and remain even 45, in order through them to achieve a reduction in GHG emissions by 90-95% till 2050 [63], [96]. These projects consist of a combination of adhoc-policies, technical, environmental, regulatory, and economic and are:

- **Improving efficiency of power plants**: The improvement takes place with **a**. gradual replacement of the efficient and more polluting thermal units **b**. operation of new NG units with the best CF and least GHG emissions, **c**. the interconnection of the islands' ESs with the mainland ones.
- **Improvement of energy efficiency of industry**: Industry consume 15,6% of total energy consumed and is responsible for the 19,3% of air-pollution. The most important projects for improvement of energy efficiency in industry are:

  1. Interventions for upgrading production systems
  2. Implementation of bioclimatic interventions in industrial buildings
  3. Rationalization of energy-intensive production systems
  4. Introduction of new efficient power saving technologies.

  In addition, the National Energy Efficiency Action Plans include policies to promote the rational use and saving of energy in all economic sectors. The concern mainly actions to improve the energy efficiency of residential buildings, hospitals, schools and the promotion of high efficiency appliances and efficient heating/cooling equipment. These actions are supported by a number of laws, which contributed to the harmonization of the respective European legislation in Greek laws (3661/2008, 4122/2013, 3855/2010 and 4342/2015).
- **Promoting green road transport**: Transports consume 15,6% of total energy consumed and is responsible for the 19,3% of air-pollution. Green transports are promoted by:

  1. Interventions in the transport network, in the public Mass Transportation Means - MTM, in all types of vehicles
  2. Introduction of smart tax measures for replacing old technology vehicles/cars with EV ones **c**. replacing of oil by biofuels and H2/NG mix. The mitigation of GHG emissions in transport is also supported by a number of institutionalized EU policies through Regulations and Directives, which have been adopted by Greek laws, 1999/94 / EC, 2009/30 / EC, 2014/94 / EU, 443/2009, and 510 / 2011.

- **Recovery of organic waste and biogas**: They consume 15,6% of total energy consumed and is responsible for the 19,3% of air-pollution A package of projects was launched for the treatment of organic waste, which significantly contributed to the reduction of biodegradable waste in modern waste treatment plants. Yet, projects were promoted for smart treatment of biological waste - recycling, energy recovery and use of sludge in agriculture as fertilizer. It is also worth noting the installation of biogas production plants in urban centers with a population of over 100.000 inhabitants, where the biogas produced used for teleheating. For the development of biogas projects, a special license-giving frame has been applied where, special conditions and criteria for environmental licensing of electricity and thermal energy production units have used.
- **Control of GHG fluoride emissions**: To control emissions from PH-GHG, two strategies have been adopted by EU and have set out in Directive 2006/40/EC517/2014. They concern air conditioning systems used in motor vehicles. The two strategies aim to prevent leakage and emissions and to control the use of fluorinated gases (Kigali Compliance Amendment to Montreal Protocol).
- **Reforms in the Common Agricultural Policy-CAP**: They consume 15,6% of total energy consumed and is responsible for the 19,3% of air-pollution. Specific Green Direct Grants have been introduced, related to the provision of environmental public goods linking sustainable food production and farmland management, and environmentally friendly practices and methods. Reducing the intensity of agricultural land use and establishing rules for the mandatory compliance of the animal waste cross-compliance system help to be reduced GHG. In addition, compliance with cross-compliance had the effect of reducing fertilizer use and consequently reducing N2O emissions. Organic farming and the reduction of the use of synthetic nitrogen fertilizers lead to a significant reduction in N2O emissions. According to national statistics, the total area with organic farming in Greece, amounts to 4.780.000 acres in 2019.
- **Policies to increase the share of RES in power mix**: Key target the share of RES to overpass 90% till 2050 in power production mix via:

  1. Penetration of biofuels in all transport means (Directive 2009/28/EC as it has been determined respectively during its harmonization in Greek law)
  2. Support of CHIP units until the year 2030 (law 4414/2016 in the form of sliding feed in premium, which is calculated from the difference of the special purchase price of the specific RES or CHIP technology).
  3. Promote of offshore P/V and W/T parks.
  4. Promote more smart public auctions, defining the min number of competitive procedures. The table below gives a sample of existed public auctions.

Table 52. Results of public auctions for power supply coming from RES 2018-2020 .

Auctions/Types	Auctioned power in (MW)	Power knocked down (MW)	Weighted reference price €/MWh
PH/V 0,1-1 MW	164	115,42	72,39
PH/V 1-20 MW	230	53,48	79,02
WInd 3-50 MW	529	330,58	64,24
Total	923	499,48	-

Source : Regulation Authority for Energy.

- **Promoting a new smart spatial planning model for RES**: it will define the certain rules for the location of RES throughout the country and will help to make known to all people in advance the completely or partially excluded areas from installation of RES. Yet, it will determine the installation conditions, taking into account criteria such as, land physiognomy, environment, RES carrying capacity and the anthropogenic activities that should be installed. From the unofficial field research done by us in 2019 among 56 regional energy opinion leaders regarding -among other-which should be the best criteria for choosing the location for RES installation their answers were collected in table 53.

- **-Adhoc legal institutions promoting the transition - Law 3851/2010:** the key new institutions promoting the transition are:

  1. Prohibition the installation of RES in farmlands characterized as highly productive.
  2. Promoting areas attracting great investment interest for RES installation costructuring adhoc infrastructure-technical lakes, grids, roads enforcing regional ES.
  3. Promoting Certain projects aiming to improve operation, control and safety of ES such as, smart grids and telemetering systems, algorithmic models forecasting on/off-peak demand points within Intraday Energy Planning-IEP system.
  4. Promoting real and virtual net metering systems for all end-users were promoted aimed at strengthening the role of the consumer power bargaining and the development of cooperative schemes to promote decentralized power generation microsystems-energy communities (offset of electricity generated by self-generating RES or CHIP stations, with the total electricity consumed).
- **Creation of new Energy Communities-ENCO (L4414/2016 & L4513/2018)**: They have legal form of an Urban Cooperative, exclusive economic purposes and important advantages: ensure economies of scale in the power systems, contribute significantly and efficiently to energy transition process, promote innovation in the energy sector, manage successfully energy poverty, promote energy sustainability via the production, storage, self-consumption, distribution, and supply subsystems, enhance energy self-sufficiency and security in small islands and improve end-use energy efficiency at local and regional level. Yet, ENCOs can, upgrade RES performance, produce cheaper power for their members, sell power to wholesalers/retailers, create energy storage and desalination systems using energy coming from their RES. The new legal framework under the above laws is very favor, flexible and provides 10 incentives strong incentives for ENCOs viability :

  1. Preferential treatment for funding by European investment programs.
  2. Preferential participation from competitive bidding procedures of L.4414/ 2016 for power produced by RES/CHIP stations.
  3. Determining special conditions for the use of services of the Last Shelter Cumulative-LSC Representation Body by RES/CHIP stations that hold energy communities.
  4. Ensuring special licensing conditions for RES/CHIP stations.
  5. Exemption from the obligation to pay the annual fee for maintaining the right to hold an electricity generation license.
  6. Priority of ENCOs applications submitted for new license of RES/CHIP stations.
  7. Reduction by 50% of the municipal taxes for RES/CHIP stations.
  8. Reduction by 50% of amounts of guarantees for their registration in the Participants Register System under the contracts of Daily Energy Planning Transactions-DEPT.
  9. Installation of RES/CHIP stations by ENCO to meet the energy needs of their members and vulnerable consumers, or citizens living below the standard of living.
  10. Provision of special conditions for ENCO working as operators of electric vehicle charging infrastructure.

Table 53. Criteria for choosing the location for RES installation as they formulated by 56 interviewed energy opinion leaders in REMTH.

Criteria*	Number	Percentage %
Solar, wind, geothermal or hydro capacity	12	29,3
The carrying capacity of area under study	9	22,0
Cost of land and accessibility	5	12,2
The existence of transmission infrastructures-mega/micro grids	5	12,2
The existence of transportation infrastructures	4	9,7
The existence of economies of scales in CAPEX and OPEX	3	7,3
The existence or not of local stakeholders reactions	3	7,3
Total	41	100,0

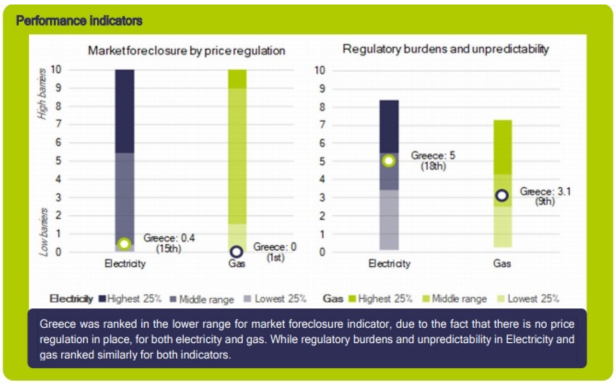
Due to some of them adopt 1-3 views we accepted that supported much more Source: Our desk research 2019 and Goletsis, GA. (2000)

- **Adhoc projects to promote RES power in heating/cooling**: Heating/cooling are two activities absorbing high % of the consumed energy, 29,5%. The promotion of power of RES and used for heating/cooling has been significantly increased since 2005 by the implementation of the specific financing mechanism called "Promotion of heating/cooling systems from RES and CHIP for self-consumption". The promoted tools are, heat pumps, geothermal energy, mandatory coverage of 60% of the needs for hot water from solar systems in new and radically renovated buildings, new buildings have to be bioclimatic consuming almost zero energy and new standards for solid biomass fuels for non-industrial use.
- **Promoting electrification in transportation with power from RES**: Transport absorbs a high percentage of gross energy consumption, about 49,5%. The reformed framework (Directive 2015/1513/EE, L.4546 / 2018) refers to the contribution of advanced biofuels with the aim of their participation of 20% on the diesel energy mix. It is allowed to be sold biofuels with oil refining products containing biofuels, determined by the decisions of the Greek Chemical Council. The most important policy for

the promotion of RES in transport concerns the obligation to mix diesel with biodiesel, and gasoline with bioethanol. The refinery plants have to mix the diesel/biofuels in portion of 7% by volume, creating the new biodiesel for transport. Respectively, there was obligation to mix gasoline/bioethanol at the rate of 1% -3,3%-4,5% for the years 2019, 2020, 2021 meaning a percentage of 5% by volume, while there is the possibility of increasing this portion after the year 2021. In Greece 17 biodiesel units operate with a total capacity of 16.000 tons, 2 in REMTH with capacity 1.630 tons- much higher than required to meet the needs of the regional market to achieve the mandatory rate of mixing diesel with biodiesel.

- **Promoting NGL/NG as interim decarbonization solution**: The promotion of NG is carried out through the implementation of favor projects such as, energy market liberalization, tax incentives, NG competitive retailing prices and dense pipeline network. In the industrial and tertiary sectors, penetration of NG is evident due to additional actions that contribute to significant benefits, socioeconomic and environmental. In the field of transport, the most important policy concerns both, less CO2 emissions by vehicles and clearer air into the cities. For this, there are generous incentives supporting the replacing classical vehicles, either by new ones fueled by NG and biofuels, or hybrid/full electric vehicles.
- **Improving energy efficiency in buildings through** :
    1. A new technical guide ruling energy efficiency of buildings' cooling/heating systems and their energy inspections, an enriched content of "Energy Performance Certificates (EPC)"
    2. The program "Saving at Home" c. project "Energy Efficiency Contracts" supporting much more energy saving interventions in both public /private buildings.

- **Improving energy efficiency in transport through**:
    1. Reform of Transport Mass Means(TMM) to increase the number of people using them.
    2. Development of sustainable urban mobility plans by promoting the "Car-Sharing System".
    3. Improving quick accessibility to transit urban stations.
    4. Introduction the "Eco-Driving System" that combines simple driving techniques with maintenance rules achieving 5-20% fuels saving and 15-30% less GHG emissions.
    5. Strong incentives for replacement of old cars by new using biofuels and electricity-hybrid.
    6. Introduction of "Ecological Marking and Energy Label" in passenger cars.
    7. Replacement of old small trucks with new meeting the specifications of EURO VI and creation of power charging stations for electric vehicles.
    8. Obligatory periodic technical inspection of vehicles through the "Vehicle Technical Inspection Centers (VTIC)". The graph below depicts the performance indicators of ES-Greek's directly and REMTH's indirectly.



Greece was ranked in the lower range for market foreclosure indicator, due to the fact that there is no price regulation in place, for both electricity and gas. While regulatory burdens and unpredictability in Electricity and gas ranked similarly for both indicators.

Fig. 15. Readiness for transition and performance of Greek energy markets. Source: EUROSTAT report 2019/2020 and HELLASTAT reports 2019/2020.

7.4. The power storage systems as tool for cope with power variability/stochasticity and quick respond to on/off-peak demand.

Investments in storage systems are key for achieving the decarbonization goal of Greece/REMTH and further penetration of RES. And this because the RES power production is stochastic and, therefore, the storage systems will be able to stock the energy surplus that will be used in due time. In near future with large storage systems we will be able to be converted RES units into base ones, eg units that will cover key loads of a spatial ES. Today, there is serious discussion about three issues, whether power storage systems are necessary, how many storage capacity we need, and which technology must be chosen for storage. The if/ how much are depended on the share of RES in the power mix. Which technology is the best depends on, how fast new P/V-W/T with at least 40% greater performance will be installed, how well the local technoeconomic conditions be able to support the introduction of such new RES technologies, whether exist large-scale hydropower stations with hydro-pumped storage systems, the degree of flexibility of ES based on hydro and NG reserve units, the existing domestic storage systems using existed technologies- batteries. In practice, for the expected future RES share of 55% in 2030, 65% in 2040, 95% in 2050, the necessary new power storage systems will amount to 13.000-15.000 MW till 2050, of which 1.750 MW is suitable for relatively limited capacity battery technology, and 1.000-1.250 MW hydro-pumped and green H2 storage system -for REMTH total 500 MW, hydro-pumped 500 MW, green H2 800 MW and batteries 200 MW. The combination of the 3 storage technologies creates synergies and produces total benefits that will exceed the € 3.000.000.0000 till 2050 for the moderate scenario. The benefits from the new storage capacity are magnified. In optimistic scenario-RES share ≥97%, will be amounted to € 5.000.000.00 (IENE 2021). An adhoc research of NTUA (2020), estimates that investments in large storage projects don't be viable in initial stages if their viability is based only on energy market forces, therefore, they need supporting incentives. According to the same study, energy storage can bring benefits to the Greek economy € 130 -REMTH 9 million/year-and this highlights not only the need to build such systems, but also the systems have to have the optimal capacity. It is estimated that a new storage capacity of 15.000 MW will be installed by 2050-for REMTH 1750 MW. Till 2021, green energy storage systems 1.000 MW have installed, costing 2 € billion. These projects have significant added value of 75%, against 50% of W/T and 65% of P/V, which can allow Greece to operate as an exporter of clean energy, in addition to enhancing its energy autonomy. The figure below shows very clear the complex role of storage in new energy era, [25], [27], [55], [105], [106], [112], [113].

Fig. 16. Services and facilities offered by storage systems. Source: International Forum on Pumped Storage Hydropower, 2020.

Since energy storage systems are, economically and environmentally, very interest and complicate topics, will have to be seen in deep. So we will consider necessary to cope with the next aspects:

- Participation of storage units in the normalization of electricity markets, either as independent participants or through representatives.
- Licensing and contracting framework with the respective National/Regional Energy Operators.
- Promoting mechanisms and tools to support investments in such systems.
- Promotion of compatibility of national/regional frameworks with a central of EU.
- Promotion of PPA contracts and the inclusion of storage stations in portfolios together with RES units for the joint activity and synergies in the electricity markets.
- Installation and efficient utilization of scattered storage units in users' facilities.

To the next table we present the storage technologies and their advantages/ disadvantages.

Table 54. Comparing the mature and new technology storage systems.

Storage technology	Advantages	Disadvantages
Pumped-hydro systems	• Technological maturity /quick response • High performance • High capacity and long life cycle • Limited auxiliary services • CAPEX =900 €/MW, no reduction trends	• Difficult to build the 2 water reservoirs required in pumped storage systems. • Spatial environmental impacts, less forests, etc.
Battery systems	• Faster response than Pumped-Hydro • Faster time for installation • Higher performance • Much auxiliary services • CAPEX =1.400 €/MW, greater reduction trends	• Small life cycle • Less safety and reliability. • Limited availability of constructed materials. • They needed recycling systems at the end of their life cycle.
Bleu H2 from converting Lignite units	• Decarbonization of lignite based power units • Low CAPEX, 2,5 €/Kg of lignite • The spatial production system remains and the existed jobs	• Greater OPEX. • The today process technology implies great emissions of CO2, but some breakthroughs promise better results.
Green H2 coming from RES-electrolysis	• The most indirect produced clear energy • It can be transferred through existed NG pipelines after some modifications • Green H2 technologies are the only storage ones that have the ability to channel stored energy to other end-use sectors such as, transport, buildings, industrial heat generation, chemical production, and electricity generation • Being one of better and cost effective storage system it is estimated that about 24TWh will be stored with such technology.	• At this time, no drawback seems to be existed.

Source: The Green Tank report 12/2020-some adaptation and compilation by author.

In conclusion, the increase of RES penetration in combination with energy storage systems based on new effective technologies can lead to a faster and better decarbonization. The next figure depicts the annual benefit of ES from the introducing of storage systems till 2030.

The figure 18 presents how the projected decarbonization path diverges from the existing trends and it should be emphasized that the challenge will be much more complex after the 55-60% target will become binding.

The figure 19 represents the CO_2 cycle and the possibilities for reduction and capture it.

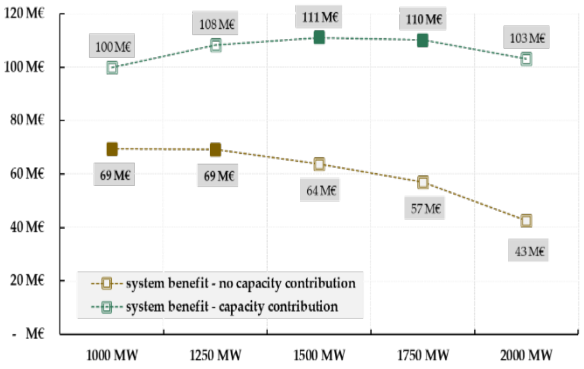


Fig. 17. Annual benefit to ES from introducing the storage systems. Source: NPEC-National Plan for Energy and Climate 2020.

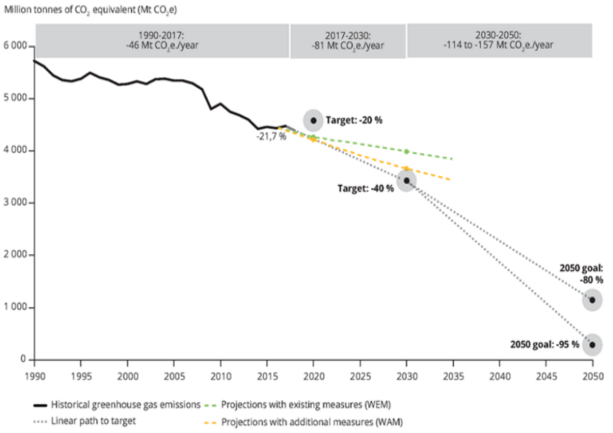


Fig. 18. How the projected path diverges from the existing trends. Source: European Environment Agency-EEA.

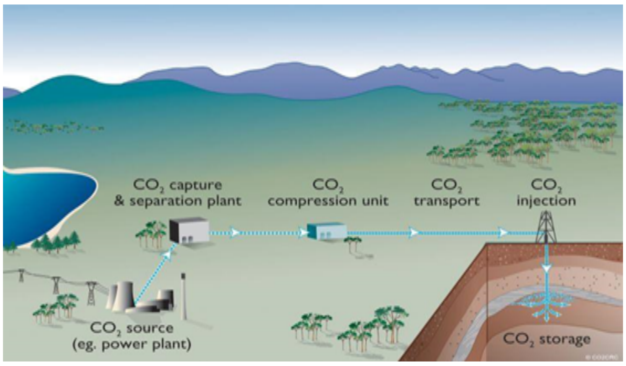


Fig. 19. The CO2 cycle and storage for reduction of its impacts on climate. Source: Luo X.; Wang J, Dooner M, Clarke J (2015) "Overview of current development in electrical energy storage technologies and the application potential in power system operation". Appl. Energy, 137, 511–536.

The next figure 20 represents the pumped-hydro storage system and the possibilities for increasing flexibility of ES.

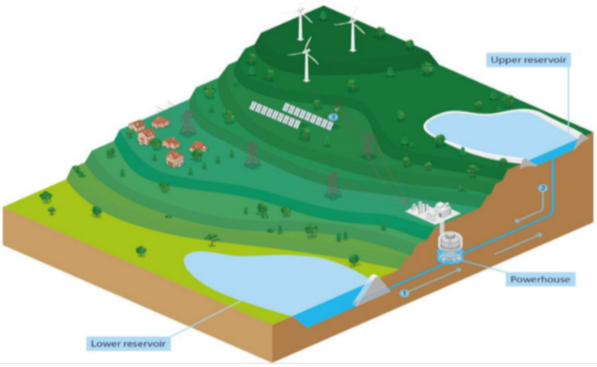


Fig. 20. Pumped-hydro storage system.
Source: Luo X.; Wang J, Dooner M, Clarke J (2015) "Overview of current development in electrical energy storage technologies and the application potential in power system operation. Appl. Energy, 137, 511–5361

The next figure 21 represents the battery storage system and the possibilities for increasing flexibility of ES.

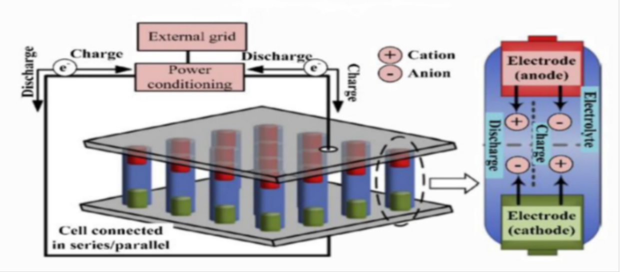


Fig. 21. Principles of Battery storage systems.
Source: Luo X.; Wang J, Dooner M, Clarke J (2015) "Overview of current development in electrical energy storage technologies and the application potential in power system operation. Appl. Energy, 137, 511–536.

The next figure represents the H2 storage system and the possibilities for increasing flexibility of ES.

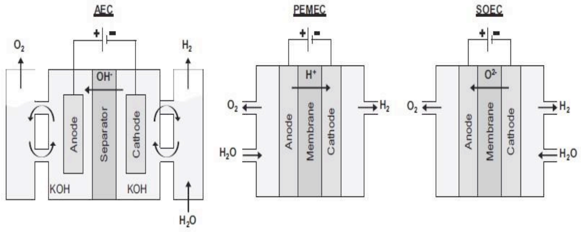


Fig. 22. Principle of operation of the 3 basic electrolysis technologies for green H2 production.
Source: Luo X.; Wang J, Dooner M, Clarke J (2015) " Overview of current development in electrical energy storage technologies and the application potential in power system operation. Appl. Energy, 137, 511–536.

The next figure 23 represents a holistic storage system and the possibilities for increasing flexibility of ES.

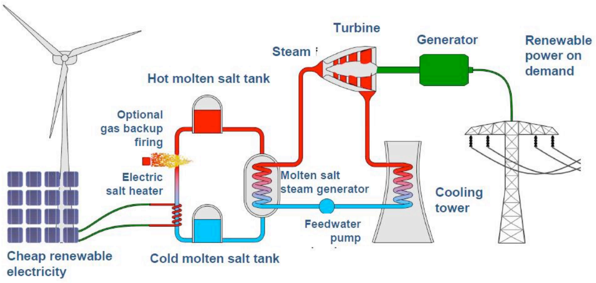


Fig. 23. Principle of operation of a molten salt storage system in combination with existing lignite combustion plants. Source: Luo X.; Wang J, Dooner M, Clarke J (2015) " Overview of current development in electrical energy storage technologies and the application potential in power system operation". Appl. Energy, 137, 511–536.

The next figure 24 represents the BEV transport system and the possibilities for increasing flexibility of ES.

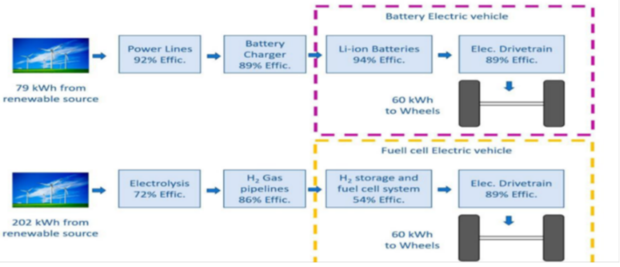


Fig. 24. BEV with battery) and electric vehicles with hydrogen cells (FCEV). Source: Luo X.; Wang J, Dooner M, Clarke J (2015) " Overview of current development in electrical energy storage technologies and the application potential in power system operation". Appl. Energy, 137, 511–536.

The next figure 25 represents an overview of current development in electrical energy storage technologies and the application potential in power system operation.

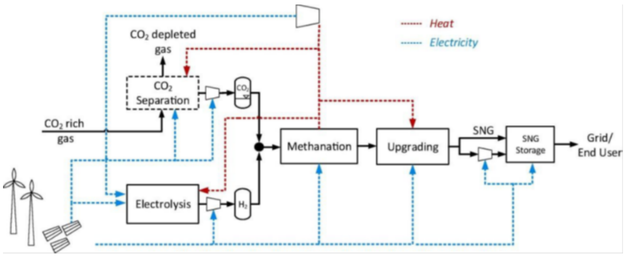


Fig. 25. Production of synthetic methane from green hydrogen and CO2 using CCS / CCU78 technologies. Source: Luo X.; Wang J, Dooner M, Clarke J (2015) " Overview of current development in electrical energy storage technologies and the application potential in power system operation". Appl. Energy, 137, 511–536.

7.5. Land-planning for best RES location in REMTH.

RES are both, environmentally friendly and consist of a key component of sustainable development. For that, RES are the key priority of the EU, Greece and REMTH, so that to ensure the best environment protection and security of energy supply. Beyond other question a special one is the best area for their installation. This is because, although RES projects can be characterized as environmentally friendly concerning their GHG emissions, they can cause other negative impacts in their surroundings. These vary, depending on the type of RES technology used, P/V, wind, hydroelectric, geothermal. The closer to urban areas are established, the greater probability to impact on anthropogenic and natural environment. In order to prevent and mitigate these effects, it is necessary to be established clear legal rules for the location of RES, reducing the risk uncertainties and conflicts of land uses. The so far right location of RES facilities in Greece/REMTH have been addressed exclusively in the context of the environmental licensing procedures of the relevant projects. These processes, although solve some problems, due to their individual approach, cannot meet the need for general common criteria and rules for optimal location RES. The criteria must ensure a common spatial framework for the RES/technology depending on, the physiognomy and the spatial peculiarities of certain areas, the capacity of RES and the special needs of development, protection, or preservation that are met in specific areas being vulnerable ecosystems, [82], [96], [106].

- **-Wind systems**: For their location, the national space is divided into three types, based on its exploitable wind potential and its particular spatial and environmental characteristics:
  1. The mainland, including REMTH.
  2. Attica region, is a more special type of mainland, due to its metropolitan character.
  3. The inhabited islands of the Ionian, Aegean and Thracian seas.

- **Solar systems**: It is proposed their location in, desert and unfertilized farmland at low altitudes of the mainland and the islands. Yet the preferably areas have to be invisible from busy areas, and with possibilities of connection with the grids of the ES. As exclusion zones for the location of P/V consider:

  1. Preserved monuments of world culture
  2. Nature and landscape areas set under protection conditions
  3. National forest parks and declared monuments of nature.

- **Biomass/biogas plants:** as suitable areas considered those located near agrobusinesses, landfills, sewage treatment plants, large livestock units, pulp production units, juice production units and industrial pulp, tomato paste, plow, or tomato paste, etc.
- **Geothermal systems:** as suitable areas are considered those having exploitable geothermal potential in quantity of hot water and enthalpy of water.
- **Small hydro-power systems**: as suitable areas considered those are being semi-mountainous and mountainous where natural water sources exist in combination with the altitude difference achieved from the water intake point to the power station, ensuring the feasibility and viability of the project. The new institutional framework for the location and licensing of new RES projects. envisages the reduction of the average time to 14 months from the current 5 years, the development of electricity storage projects with an installed capacity of at least 3,5 GW by 2030 and the increase of capacity in electricity network for the integration of more RES units.

7.6. The key-obstacles for a cost-effective transition in national/ regional level.

Despite the progress that has been made in transition, Greece/its regions face a number of obstacles to this process- even European Commission notes them in its overtime reports. Such obstacles have an additional cost equal to 22,4% of transition projects costs. For that EU recommends all members to establish a stable and flexible regulatory framework that will provide sufficient and security to energy market participants, reducing the frequency of regulatory interventions. The reports obstacles are identified by grouping them as follows:

- **Regulatory disincentives**: arise as a consequence of the very rigid and interventive regulatory framework for the operation of the electricity and NG retail markets.
- **Market disparities/disincentives**: arise from the existence of unequal conditions of competition for different types of suppliers. Some market players already have a competitive advantage, controlling high market share and this has to be eliminated. If market rules do not prevent this kind of suppliers who should manipulate the markets to the detriment of competition, they will put invisible artificial serious barriers to right competition.
- **Procedural incentives**: arise as a result of the complexity and differentiation of power standards and procedures at national and regional levels, affecting negatively new entrants in retail energy markets. These obstacles are relevant to, licensing, registration, and compliance with procedural functions, as well as access to data.
- **Institutional disincentives**: refer to ensuring conditions of lasting consumer protection. End-users must be able to change supplier anytime. If they cannot change supplier, then suppliers do not have any incentive to improve their services offered, reducing prices /KWh, or promote innovative business practices to attract new customers.
- **Disincentives from social reactions for location of P/V-W/T**: Despite the rich wind potential of the Greek mountains and the greater performance of new technology

-of course having higher CAPEX/MW and being capital and know-how intensity- sometimes local societies react to accept the installation of such new technology P/V and W/T in municipal lands. Studies supported by EC estimate that in Greece, a good solution is the offshore installation of P/V and W/T by floating systems. These offshore systems will exploit at least 10% of the 263 GW available marine wind potential-and in Thracian sea is 12,9 G and the better solar radiation [106].

8. Sub-Part C: The Step-By-Step Roadmap To Transition In Remth

8.1. General approach to REMTH's transition roadmap: rules, data, predictions

We start with the three basic remarks and imperatives related to energy transition not only the REMTH but, Greece as a whole and EU.

- EU has provided its members with all the necessary tools, strategic goals, proper innovation ecosystems and financing instruments so that to be eased towards the transition.
- Efficient power production and saving technologies must drive energy demand down for the first time in EU history.
- RES production has to rise so that their share in power mix to overpass 90% and GHG emissions to be nullified.

The way Greece/REMTH perform their energy transition will have to reflect the collective transition roadmap of EU. Beyond the key goal of EU all members to provide clean, secure, and affordable energy to all clients, it claims that transition is a great opportunity all members to be done more competitive and energy just. To this context, EU urge its members to promote a more science-based approach to complete decarbonized economy, relying on 3 relevant scenarios to be discussed in each of them-pessimistic, moderate, optimistic. Yet, EU promotes holistic transition approaches based on spatial basis so that every country or region to adapt general guidelines to its needs. A complementary way to be boosted the transition is the creation pools of citizens/stakeholders involved in the decision-making process, not only to make it more democratic, but also more efficient. For instance, a regional "Energy Transition Assembly" might include citizens representing various relevant societal segments such as, MPs, mayors, representatives of the scientific community, farmers, businesses, energy operators, trade unions and NGOs. Along with previous, additional actions need to be taken by local stakeholders like, public sector to support private one for strong R&D activities that can increase local firms' propensity for innovative investments. REMTH should become a regional key-provider of clean energy boosting its conventional and innovation businesses.

Finally, a spatial decarbonization process can be successful if only be just and understandable by local societies. So, given the REMTH's negative peculiarities- low growth rates, strong deindustrialization, weak structure of economy, demographic problems, high unemployment rate, a smart transition process should ensure a better development future. It needs an adhoc transition plan being well-adapted to its capabilities. Yet, other regions with already successful transition practices can be a useful guide for transition planning of REMTH. To the next tables we give the national goals of energy upgrading and transition. From these national goals we planned the REMTH's one doing all the necessary adaptations. The planned goals have been quantified and after some compilations and adaptations were elaborated by inferential statistics.

Table 55. Investment priorities and goals provided by ESPA 2014-2020 aiming to increase RES share in energy.

Investment priorities	Adhoc goal	Actions
Improving energy efficiency and security of supply through energy distribution, storage, and transmission systems and using it	Increase of NG share till 2010-after gradually reducing	Development of mid-low pressure NG networks
Support for better energy efficiency, smart energy management and RES use in public infrastructure and housing	Energy upgrade of public infrastructure	Energy upgrade of public buildings in all sectors
Promoting production and consumption of energy from RES	Increasing the use of geothermal energy for thermal applications	Development of infrastructure and applications for the utilization of geothermal energy in urban, rural and industrial areas.

Source: ESPA 2014-2020, elaboration in regional basis by author.

Table 56. The key goals put for transition of Greek energy system.

The structure of future electric system of Greece	2030	2040	2050
Total power generation in MW	22.100	33.000	38.920
Total electricity demand in GWh	58,6	63,0	71,0
Energy mix			
Lignite in MW	0,0	0,0	0,0
Natural Gas in MW as reserve power stations after 2040	2.106	1.700	1.320
Ph/V RES in MW	8.820	12.000	14.400
Ph/V performance 1MW =X GWh	1,7	1,8	2,0
Wind/RES, inshore and offshore, in MW	7.374	15.300	18.500
Wind/RES performance 1MW =X GWh	1,8	1,9	2,0
Other RES in MW	550	700	1.200
Hydro in MW	3.250	3.300	3.500
Energy storage systems in MW-Pumped hydro	1.000	1.200	4.000

The structure of future electric system of Greece	**2030**	**2040**	**2050**
Total GDP in €2005 billions	210	280	350
GHG emissions reduced comparing to 2005 as %	55	70	80
Share of RES to power consumption as %	45	75	90
Energy efficiency as MWh/1 million € GDP	4.230	5.540	6.560
Electricity grids interconnection within EU countries as % of total	10,0	30,0	60,0
Number of smart meters as % of total ones	25,0	95,0	100,0

Source: Ministry of energy and environment report 2020 - IENE report 2020 - RAE report 2020 calculations, compilations, and adaptations by author

The next table gives both, in long run and regional basis the goals put for transition of REMTH's energy system. The quantitative data have come from those of national basis ones after their elaboration and adaptation.

Table 57. The key goals put for transition of Greek energy system.

The goals and future structure of ES of REMTH IN cumulative basis	**2021**	**2030**	**2040**	**2050**
Total power generation in MW	1.723	2.200	3.650	4.240
Total electricity demand in GWh	2,6	3,0	3,4	4,7
Total power produced in GWh	4,43	13,67	19,55	18,48
Percentage % of national production	9,3	20,2	22,4	24,4
Energy mix				
Lignite in MW	0,0	0,0	0,0	0,0
Natural Gas in MW as reserve power stations after 2040	486	2.200	1.700	320
Total power produced in GWh	1,23	6,8	5,7	1,6
P/V RES in MW	398	820	1.700	2.400
P/V performance 1MW =X GWh	0,56	2,46	5,30	9,60
W/T, inshore and offshore, in MW	490	874	1.300	1.500
W/T performance 1MW =X GWh	1,3	2,8	4,5	5,0
Other RES in MW	9	50	70	100
Produced power in GWh	-	0,03	0,05	0,08
Hydro in MW	486	500	520	550
Produced power in GWh	1,34	1,58	2,00	2,20
Energy storage systems in MW-Pumped hydro	300	500	750	1.700
Total GDP in €2005 billions	7,2	8,8	10,5	15,0
GHG emissions reduced comparing to 2005 as %	20	55	70	80
Share of RES to power consumption as %	35	45	75	94
Energy efficiency as MWh/1 million € GDP	4.320	4.980	5.690	6.860
Electricity grids interconnection within EU countries as % of total	8,3	10,0	15,0	40,0
Number of smart meters as % of total ones	1,4	20,0	90,0	100,0
Average CO2 emmitions /MWh of REMTH's ES (2020=593 Kg/MWh)	535	250	150	30

Source: Ministry of energy and environment report 2020-IENE report 2020-RAE report 2020 calculations, compilations, and adaptations by author.

It is important to see the needed investments for an effective transition in overtime basis. It is known in statistics that "the longer-term prediction, the less accuracy results". So, the 30 years forecasts for future energy demand, power production mixes, GHG emissions, better technologies of RES for greater CF and how much investments they needed to be carried out include errors type I/II. We consider interest to forecast by regression analysis a mid-term development in energy sector in REMTH till 2030, and then based on these forecasting results with greater accuracy, we will proceed to further predictions for 2040, 2050 with an accuracy about 85-90%.

Table 58. Predictions for investments in REMTH's energy sector in the period 2021-2030

Description	**Estimated**	**Invest € mil-Greece**	**Invest € mil-REMTH**
Pipelines, NG networks and other facilities	• Development of urban and peripheral networks (city grids) • Cross border pipelines • Underground warehouse in South Kavala • LNG terminals-included the FSRU of Alexandroupolis and A. Theodor and additional works at Revithoussa station	1200 300 400 900	
Semi total		2.800	195
New power production plants of NG and storage systems	• New NG power plants-CCGT • Energy storage systems, including batteries and hydro-pumps	1.100 2.500	
Semi total		3.600	250

Networks-grids	• Upgrade and expand the existing network and interconnect two islands, including new high voltage transmission lines	7.500	500
RES	• Small hydroelectric	100	
	• Wind parks, onshore 35% and offshores 65%	4.500	
	• P/V parks	3.200	
	• Concentrating Solar and P/V Power parks	500	
	• Biomass, including liquid biofuels	650	
	• Geothermal high and low enthalpy	500	
Semi total		9.950	700
Improving energy efficiency	• Building's energy upgrading, private and public	11.000	750
Solar systems applicable in households and commercial firms	• Solar heating systems in hotels, industry, housing, maintenance, replacement, etc.	1.500	75
R&D	• Research and innovative applications	1.000	60
Total		29.850	2.530

Source: Elaboration by regression analysis adaptations and compilations by author.

To the next table, the above national quantitative transmission goals were evaluated and ranked related to their degree of importance and are presented as estimations in time needed for their completion.

Table 59. Activities and institutions proposed for REMTH's cost-effective transition: X=Least, XX=Least to Moderate, XXX=Moderate, XXXX= Moderate to Best, XXXXX=Best.

Actions, activities, and institutions	**importance**	**Estimated time**
Emissions reduction adapted to region's energy conditions		
Reduction GHG emissions and fluorinated gas emissions -increase absorptions of them	XXXXX	25 years
Reduction of emissions from conventional power plants	XXXX	8 years
Promotion of natural gas as an intermediate fuel for the decarbonization of the energy system	XX	15 years
Promotion of RES, mainly PV/P and W/P	XXXXX	25 years
Improvement of energy efficiency in buildings, industry, and infrastructure	XXX	12 years
Reduction of emissions in the transport sector	XXX	25 years
Reduction of emissions in the agricultural sector	XXX	20 years
Reduction of emissions in the tourism sector	XXXX	15 years
Promotion of RES adapted to region's energy conditions		
Promotion of new technologyy RES	XXXXX	15 years
Achieving zero operating aid for economically competitive energy sources	XXX	12 years
Proper operation of licensing and spatial planning framework	XXXX	10 years
Promoting dispersed RES systems and strengthening the participatory role of local communities	XXX	18 years
Integration of RES in the new smart national and regional macro/micro grids	XXXX	15 years
Regulatory obligations of minimum RES participation in the coverage of energy needs in the building sector	XXX	15 years
Improve the use of RES systems to meet thermal and refrigeration needs	XXXX	12 years
Connection of energy sectors to enhance optimal RES penetration synergies/supplementary	XXX	15 years
Promoting the use of biofuels in transport	XXXX	15 years
Energy efficiency performance adapted to region's energy conditions		
Improvement of energy efficiency of public and private buildings	XXXX	15 years
Promotion of smart energy market mechanisms for control of immoral practices	XXX	15 years
Improving the energy efficiency of transport	XXXX	15 years
Improvement of energy efficiency of electricity production, transmission, contribution and infrastructure	XXX	15 years
Smart modernization of water supply sewerage and irrigation infrastructure systems	XXX	10 years
Security of Supply adapted to region's energy conditions		
Increasing the diversification of energy sources /suppliers, promoting storage and demand response	XX	15 years
Reduction of energy dependence from energy imports-it has to be less than 2-5% in the worst case	XXXX	18 years
Preparation of the region involved bodies to deal with the unpredictable outage of energy supply	XXXX	15 years
REMTH's Energy Market smart operation adapted to region's energy conditions		
Strengthen interconnection with neighboring regions ES for electricity transmission	XXX	12 years
Enhancing competition in the electricity and NG markets regional basis	XXX	15 years
Consumer protection and tackling energy poverty	XXX	15 years
Promotion of NG transport, distribution, and storage infrastructure projects	XX	15 years
Research innovation and competitiveness in horizontal and vertical /sectoral basis		

Promotion of innovative energy saving technologies	XXXXX	12 years
Promotion of innovative carbon detoxification technologies	XXXX	12 years
Digitalization of energy networks, grids, distribution to end users using smart tele-measuring systems	XXX	15 years
Promotion of innovative electrification technologies in transport	XXX	15 years
Promoting entrepreneurship through research and innovation actions integrated in the regional market	XXX	13 years
Framework to support the implementation of smart energy investments to improve competitiveness	XXX	12 years
Promotion of circular social economy and cyclical entrepreneurship	XXX	10 years

Source: Ministry of energy and environment report 2020-IENE report 2020-RAE report 2020 calculations, compilations, and adaptations by author.
Source: Green Tank report 12/2020-Energypress.gr.

In order someone to shape an idea regarding the so far successful completion of goals put in past for transition -for instance 20-20-20 EU project, or whether Greece/REMTH are capable to achieve a cost-effective transition and good results till 2030, we give the table below where the projected and carried-out goals are depicted. For predictions we used the overtime data 2012-2020 which were elaborated via the classical regression model. The same model will be used for all predictions for the periods 2040 and 2050.

Table 60. Greece: goals put and degree of their implementation to milestones 2020-2025-2030.

Goals put and degree of their implementation/ Milestones -amounts in € millions	**Sector**	**Year starting**	**2020 done**	**2025 prediction**	**2030 prediction**
Improvements to conventional power generation system	Energy	1996	11.700	8.200	5.500
Promotion of NG in the domestic sector	Energy	1998	2.304	330	366
Promotion of NG in the industry	Energy	1996	671	861	1,094
Promotion of NG in the transportation sector	Transportation	1999	17	20	22
Promotion of NG in the power production sector	Energy	1994	15,000	19,000	25,000
Use of biofuels in transport	transportation	2005	650	810	960
Implementation of energy efficiency measures in industry	Industry	2008	300	400	500
National Action Plan for Energy Efficiency Implementation of energy efficiency measures in the domestic and tertiary sector (National Energy Efficiency Action Plan	Energy	2008	2.930	3.500	4.000
Measures for road transportation	Transportation	1983	340	500	600
Recovery of organic waste	Waste management	2002	800	900	1000
Biogas recovery	Waste management	2002	500	600	700
Reduction of fluorinated gas emissions	Industry-cooling	2004	460	1400	2300
New Common Agricultural Policy, Green Direct Aid: reducing the intensity of agricultural land use and improving animal waste management	Agriculture	2007	430	500	600
Rural Development Program (RDP): Increase in organic crops	Agriculture	2007	350	400	450
Reducing Fertilizer Use by 60% within 20 years	Agriculture	2007	125	150	200

Source: Ministry of Environment and Energy- Ministry of Agriculture Development and Foods-adaptations and compilations.

Table 61. REMTH: goals put and degree of their implementation to milestones 2020-2025-2030.

Goals put and degree of their implementation / Milestones	**Sector**	**Year starting**	**2020 done**	**2025 prediction**	**2030 prediction**
Improvements to conventional power generation system	Energy	1996	245	10	25
Promotion of NG in the domestic sector	Energy	1998	320	730	50
Promotion of NG in the industry	Energy	1996	35	48	57
Promotion of NG in the transportation sector	Transportation	1999	1	2	3
Promotion of NG in the power production sector	Energy	1994	310	1.020	150
Use of biofuels in transport	transportation	2005	12	83	106

Goals put and degree of their implementation / Milestones	Sector	Year starting	2020 done	2025 prediction	2030 prediction
Implementation of energy efficiency measures in industry	Industry	2008	30	40	50
National Action Plan for Energy Efficiency Implementation of energy efficiency measures in the domestic and tertiary sector (National Energy Efficiency Action Plan	Energy	2008	76	20	30
Measures for road transportation	Transportation	1983	50	50	60
Recovery of organic waste	Waste management	2002	2	6	20
Biogas recovery	Waste management	2002	5	15	72
Reduction of fluorinated gas emissions	Industry-cooling	2004	2	4	2
New Common Agricultural Policy, Green Direct Aid: reducing the intensity of agricultural land use and improving animal waste management	Agriculture	2007	30	50	60
Rural Development Program (RDP): Increase in organic crops	Agriculture	2007	31	42	45
Reducing Fertilizer Use by 60% within 20 years	Agriculture	2007	12	15	20

Source: Ministry of Environment and Energy- Ministry of Agriculture Development and Foods-adaptations and compilations.

The next table presents numbering all energy projects including those with multiple categorization, or projects applied to more than one sector, as well as their analysis in the different categories of transition measures.

Table 62. Distribution of existing policy measures to the various sub-targets and categories of measures being in force in Greece / REMTH.

Measures of energy policies	RES in power production	RES power for heating /cooling systems	RES power for transports
Regulative /institutional	22	8	11
Technical /infrastructure	4		1
Economic/technoeconomic	3	4	2

Source: Ministry of Environment and Energy-adaptations and compilations by author.

In general, the suggested transition projects aimed and aim to create a better simplified frame and a mechanism that will disseminate the advantages of transition to all stakeholders and local societies. Even that, the local know-how and knowledge that will be produced, will promote a more competitive regional economy. The phase out from fossil fuels of REMTH's economy will push it to new innovative decarbonized eco-productive systems with greater know-how added value. The proposed transition projects will bring together a wide range of global extensive expertise and experience with our applied research on regional level. The priorities put include:

- **Strengthening** understanding the speed and scale of carbon-based economy phase out.
- **Clarifying** decarbonization transition trends, drivers, and scenarios at regional level.
- **Identifying** policy challenges and priority responses for accelerating the phase out from its carbon-based economy.

The key-components of such policy are, optimal power generation mix, energy security and affordability, a just transition for protection of vulnerable people, strengthening economic and employment outcomes, securing resources required for financing the transition, building public support for accelerating the just and well managed phase out of carbon-based economy.

8.2.Financial funds/sources for finance investments for transition of REMTH

Transition process needs best planning, good understanding from local societies, well experienced energy project managers and the proper financial sources. To the next a brief description of European, national, and regional sources /funds projects/programs for finance energy transition actions and projects is presented:

1. General European Financing Sources

- **European Regional Development Fund (ERDF)**: Promotes the balanced development in 273 European regions.
- **European Social Fund (ESF)**: Supports employment projects across European regions.
- **European Cohesion Fund (ECF)**: Finances projects in the transport sector in regions with an average gross national income per capita less than 90% of the EU average.
- **European Agricultural Fund for Rural Development (EAFRD)**: Focuses on addressing the challenges facing the EU's 52 rural regions like REMTH, where agriculture sector contributes to GDP more than 12%.
- **European Maritime and Fisheries Fund (EMFF)**: Helps fishermen to adopt sustainable fishing practices in114 coastal regions in order to diversify their economies.

Remarkable differences exist when we compare the current programming period 2014-2022 (n+2) with the new one 2022-2030 regarding energy projects:

1. The financial tools are lot and more effective
2. The importance of repayable aid, given through financial tools have increased
3. Grants/ allowances are generally reduced
4. It is possible to be combined resources of different financial sources so that through leverage to be yielded better results.
5. Increases the recycling % of resources comparing to those the former decade.

2. Adhoc European programs

- **Horizon 20-20-20**: Is the largest European Research and Innovation Program, availing budget of €80 billion.
- **Connecting Europe Facility (CEF)**: Finances special projects, employment, SME's actions for higher competitiveness and projects for cross-border cooperation in the energy, transport and telecommunications sectors [17], [18], [21], [40], 64].
- **InvestEU**: Focuses on, sustainable energy digitization infrastructure projects, research and innovation projects, social investments linked to energy. Also it boosts "Juncker Project 2014-2020" through of its central pillar, the European Strategic Investment Fund (EFSI) and by its cooperating with the strategic partner, European Investment Bank Group (EIB).

3. Special programs related to climate change and energy

- **Just Transition Fund, JTF**: It will be endowed with new € 7.5 billion, beyond those coming from the next long-term EU budget 2021-2030.
- **EU Emissions Trading Scheme, EU-ETS**: Will be the European GHG Emission Reduction Mechanism. Part of the income from the EU/ ETS will be used to promote energy efficiency policies.
- **LIFE**: Is the EU 's financial tool for boosting environment and climate change projects.
- **European Investment Bank (EIB)**: Aspires to become a "Climate Bank", but after 2021 it will stop to finance NG projects, something bad for EU due to very expensive NG owed to Russian invasion in Ukraine and Greece/REMTH where such infrastructure do not exist.
- **European Bank for Reconstruction and Development EBRD**: Finances projects in the transport, energy and water supply-sewerage infrastructure sectors

4. National Financial Sources:

- **Public Investment Program PIE**: Includes projects that are financed purely from national resources.
- **Co-financed Public Investment Program CF-PIE**: Includes projects co-financed by it, European funds/programs, and other International Financing Organizations.
- **National Development Program (NDP) of Law 4635/2019**: Is a mid-term development project for utilization of national resources of the EIP.
- **Infrastructure Fund**: Aims to finance the private and public sectors in joint-venture schemes (Public-Private Partnerships-PPP) for implementation of small/medium-sized projects, with an emphasis on the energy, environment, and urban development.
- **National Implementation of ETS**: Its revenue come from the trade of GHG emissions through the Green Fund.
- **Green Fund**: Aims to support projects that can, promote and rehabilitate environment and serve the public and social interest.
- **National Energy Efficiency Fund (NEEF)**: Is the basis for creation a new smart financial mechanism that will combine subsidies, financial guarantees and loans, aiming to finance projects to improve energy efficiency.
- **LIFE IP-Adapting GR**: It focuses on energy adaptation projects for climate protection like "Saving energy to my House" a very successful project for upgrading buildings saving performance.
- **ELECTRA**: It aims to saving energy in public/ private buildings.
- **Energy Efficiency Contracts-EEC**: For financing green projects.
- **Self- Power Generating and Energy Metering System**: For financing energy upgrade of residential buildings and vulnerable households.
- **Energy Communities**: A very successful cooperative project, to which participate individuals and Organizations of Local Government and Legal Entities of Public and Private Law Greek.
- **Hellenic Energy Stock Exchange-HESE**: It is an adhoc Stock Exchange Trading Platform in the context of energy markets, expanding the development possibilities of REMTH as energy hub in SE Europe.
- **Operating and Investment Incentives**: For financial support of RES through the Special RES Account (SRES-A).
- **Tender/Auction Procedures for Energy Saving**: It offers financial support for energy saving actions in sectors with high save-potential, such as the industrial and tertiary sectors.
- **Green Bonds**: Are the most important financial tool towards the energy transition. Their role is to financing large scale green projects that have positive environmental and climate benefits. Most of them issued are green "use of proceeds" or asset-linked bonds. Proceeds from these bonds are strictly earmarked for green projects and backed by the issuer's entire balance sheet. They have some additional transaction costs because issuers must track, monitor, and report on use of proceeds.

The next table gives valuable information for this kind of bonds.

Table 63. Description of green bonds that should support the finance of large-scale transition projects.

Types	Proceeds	Debt resources	Cases
Proceed bonds	Destinated for green projects	Same credit rating applies as issuer's other bonds	Climate awareness bonds backed by EIB-European Investment Bank
Revenue bonds	Destinated for green projects	Revenue streams from issuers through	Backed by fees of

		taxes, fees, and are collateral for the debt	electricity bills
Project bonds	Ring-fenced for adhoc underlying projects	Recourse is only the projects' assets	Supported by banks and funds
ABS bonds	Re-finance portfolios of green projects	Resource is solar/wind leases or green mortgages	Green covered bonds
Covered bonds	Earmarked for eligible green projects	Resource is bond issuers	Green covered bonds
Loan bonds	Earmarked for eligible green projects	Full recourse for borrowers in the case of unsecured loans	Supported by banks and funds

Source: IEA report 2020, RAE report 2021

8.3. Greece and REMTH's readiness for transition-measuring it with indices

Transition means countries/regions to transit from an energy mix based on fossil fuels to a new where RES cover at least 90% so that the GHG emissions to be nullified. It can be done through edge technologies that are important tools to facilitate higher penetrations of RES. Readiness for such edge solutions is the condition of having the necessary economic, political, technical, and social preconditions for an effective deployment of related technologies a at scale. Readiness is measured via indexes that were formed based on factors which influence the transition dealing with spatial readiness for edge technologies. The need for edge solutions is driven by the need for flexibility in the ES because edge solutions can be used to enable flexibility. ES with high penetrations of RES need more flexibility due to the inflexible power production. Regions with significant RES or with large climate change mitigation policies require more RES. For energy new technologies, whether an area is ready to scale up these technologies, is influenced by policies, regulations, markets, and social structures, in addition to whether the technologies themselves are 100% developed and compatible with existing ES. Yet, the spatial readiness score is composed by technical, political, social, and economic readiness, for edge solutions. Because the spatial readiness for edge solutions cannot be directly measured, an adhoc framework of factors which influence the readiness was developed by me. These factors are measurable indicators and chosen as independent inputs, (Center for Climate and Energy Solutions, "California Cap and Trade," Policy Hub, 2020). REMTH's ES is a miniature of the national one by 80% and this helped us in doing more easily a technoeconomic analysis of readiness for transition. It is noted that the official databanks have overtime statistical information in timeseries form mainly in national level and less in regional one. In any case, REMTH will have to meet the 10 rules set by EU for all its regions aiming to help them to achieve an effective in time and cost transition. Majority of policy makers in REMTH and Greece believe that transition is a good opportunity for 273 EU regions to be done more competitive and energy just. EU has all the needed tools, policy goals, innovation ecosystems, skilled workers, and financial to lead the global clean energy race. Yet, EU can perform the transition so that it does not require significantly different amounts of investment, compared to those needed to maintain the current ESs based on imported fossil fuels. EU also can ensure that the transition will not be simply a transition, but a just transition for all. People/societies. More than 50 million Europeans are at risk of energy poverty- so energy transition gives the opportunity to be eradicated energy poverty in EU, because transition is swifter, cheaper and more democratic when it is powered by all people of a region. Examining REMTH regarding its readiness to transition we will to information, the today energy condition, the future goals and the way-needed time and money- to capture the goals put in advance. The goals of energy transition in regional level are the below, [24], [32], [104], [106].

Table 64. The goals put for transition of REMTH's energy system-moderate scenario-money basis.

The goals and future structure of ES of REMTH IN cumulative basis	2021	2030	2040	2050
Total power generation in MW	1.723	2.200	3.650	4.240
Total electricity demand in GWh	2,6	3,0	3,4	4,7
Total power produced in GWh	4,43	5,76	9,55	11,48
Percentage % of national production	9,3	12,2	14,4	16,7
Energy mix				
Lignite in MW	0,0	0,0	0,0	0,0
Natural Gas in MW as reserve power stations after 2040	486	2.200	1.700	320
Total power produced in GWh from NG	1,23	6,8	5,7	1,6
P/V RES in MW	398	820	1.700	2.400
P/V performance 1MW =X GWh	0,56	2,46	5,30	9,60
W/T, inshore and offshore, in MW	490	874	1.300	1.500
W/T performance 1MW =X GWh	1,3	2,8	4,5	5,0
Other RES in MW	9	50	70	100
Produced power in GWh	-	0,03	0,05	0,08
Hydro in MW	486	500	520	550
Produced power in GWh	1,34	1,58	2,00	2,20
Energy storage systems in MW-Pumped hydro	300	500	750	1.700
Total GDP in €2005 billions	7,2	8,8	10,5	15,0
GHG emissions reduced comparing to 2005 as %	20	55	70	80
Share of RES to power consumption as %	35	45	75	94
Energy efficiency as MWh/1 million € GDP	4.320	4.980	5.690	6.860
Electricity grids interconnection within EU countries as % of total	8,3	10,0	15,0	40,0

Number of smart meters as % of total ones	1,4	20,0	90,0	100,0
Average CO2 emissions /MWh of REMTH's ES (2020=593 Kg/MWh)	535	250	150	30

Source: Ministry of energy and Environment special report.

It is interesting to evaluate the REMTH's transition performance in time basis- eg which of two aspects the rapid, or the rapid transition, has more advantages in qualitative/ quantitative terms. In the table below we present the advantages of each scenario based on global literature and our adapted methodological practices.

Table 65. Evaluation of 2 transition scenarios-the rapid and the gradual.

Gradual transition	**Rapid transition**
Focus on total demand (stock) and argue that new energy technologies are relatively small and will take decades to overtake fossil fuels.	Focus on change and argue that new energy technologies will soon make up all the growth in energy supply.
Argues that new energy technologies are expensive and face insoluble economic or technical impediments to growth, meaning that growth rates will be only linear.	Argues that solar and wind are already cheaper than fossil fuels for the generation of electricity and that EV are about to challenge the Internal Combustion Engine (ICE) on price, that the barriers to growth are soluble for the foreseeable future, and that these disruptive new energy technologies will continue to enjoy exponential growth. They anticipate the rise of new technologies such as green hydrogen which can lead to further waves of change.
Argues that it is necessary only to model policies which we know will happen, that the forces of inertia are very powerful, and that policymakers will remain cautious and slow-moving.	Argues that the forces for change are greater than those for inertia, and that technology opens up the opportunity for regional policymakers and regulators to design markets to better provide for all end-users' needs. Modelling only the existing policy environment has the impact of understating trends in policy making
Argues that the emerging markets (including China) will broadly follow the path taken by developed markets and use more fossil fuels as they get richer and energy demand rises.	Argues that the emerging regional markets will enjoy an energy leapfrog to new energy technologies and significantly less energy-intensive forms of economic development while providing critical improvements in the quality of life.

Source: RAE report 2020.

A question is if there any relation between the speed of transition expressed by CO2 emission/year intensity and how the cost of transition changes in relation to time. The figure below depicts this relation, showing indirectly the impact of transition speed to cost of transition. The cost is highly correlated to time, r=-072, fact leading to result "for certain projects necessary for transition, the less time will be spent, the less will cost the projects".

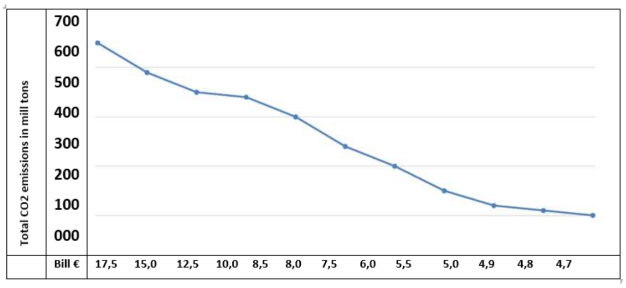


Fig. 26. REMTH: Compensation curve between total CO2 emissions and total needed costs for a specific binding CO2 emission limitation-cost in billion € --Source: IENE report 2020 for Greece- adaptation for REMTH by author.

Another interesting issue is whether there is any relation between transition speed and the cost of certain steps of transition and the next figure shows this relationship between the energy transition speed and certain steps of transition. The greater positive relation exists between level of efforts and accumulative efforts, following by rule of efforts.

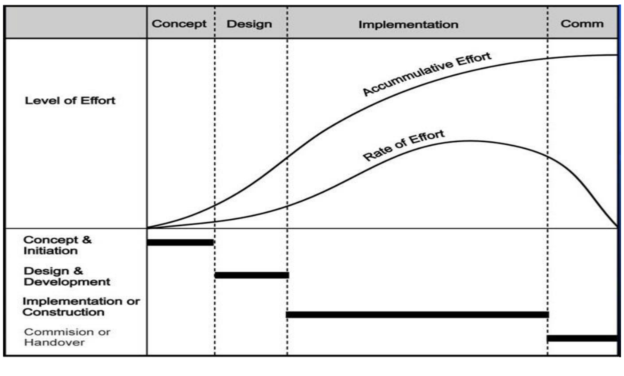


Fig. 27. Relationship between the energy transition speed and steps of transition- Source: https://www.thefreedictionary.com/Large-scale+project

Conclusively, regarding the performance and transition speed of REMTH they have related with time and cost implementation. To this issue major challenges are intermittency, inflexibility of RES, increasing demand from electrification of heating, cooling, and transportation. To balance above mismatches will be needed great attempts by all stakeholders. A basic tool should be the energy edge technologies able to facilitate faster penetrations of RES and to mitigate climate change. Many factors influence whether and which edge solutions are appropriate for a particular region-to our case REMTH, or how ready this region is to deploy them at scale. Therefore, adhoc indexes have created by IEA and WEF to assess a region's relative readiness for edge transition solutions.

The overall scores can be used to identify locations of interest, while index components can yield insights into opportunities and barriers in a specific region. The next tables show the key-factors connected to spatial energy transition readiness of REMTH.

Table 66. System performance score for showing indirectly the readiness of REMTH.

System performance score for showing indirectly the readiness -% impact by case	Energy access and security	Environmental sustainability	Economic growth - development
Security of supply	70	00	00
Quality of supply	20	00	00
Energy access	10	00	00
CO2 emissions/capita	00	30	00
Carbon intensity	00	30	00
Energy intensity	00	20	00
Air pollution	00	20	00
GDP contribution	00	00	25
Cost of externalities	00	00	30
Fossil fuels subsidies	00	00	20
Industry competitiveness	00	00	15
Affordability	00	00	20
Total	100	100	100

Source: insight Report Fostering Effective Energy Transition 2020 edition of WEF-adaptations and compilations to REMTH's condition by author

Table 67. System of transition readiness score of REMTH.

Transition readiness score	Energy system secure	Quality of human capital	Infrastructure and innovative business environment	Institutions and governance	Political commitment	Capital and investments
Fossil fuel dependency electricity energy mix	50	00	00	00	00	00
Electricity energy mix	40	00	00	00	00	00
Rate of energy demand growth	10	00	00	00	00	00
Jobs in RES sector	00	65	00	00	00	00
Quality of education	00	35	00	00	00	00
Innovative business environment	00	00	45	00	00	00
Transportation infrastructure	00	00	30	00	00	00
Trade logistics	00	00	25	00	00	00
Financial conditions	00	00	00	50	00	00
Rule of laws	00	00	00	35	00	00
Transparency-political stability	00	00	00	15	00	00
Quality of energy supply	00	00	00	00	50	00
Commitment to intern agreements	00	00	00	00	50	00
Recent investments to RES	00	00	00	00	00	45
Easy access to capital	00	00	00	00	00	25
Ability to invest	00	00	00	00	00	20
Level of energy know-how issues	00	00	00	00	00	10
Total	100	100	100	100	100	100

Source: Insight Report Fostering Effective Energy Transition, 2020 edition of WEF-adaptations and compilations to REMTH's condition by author

Table 68. Key factors connected to spatial energy transition readiness -the case of REMTH-evaluation scale 1-10.

Political	Social	Economic	Technical
Government in cooperation with local government will invest in clean energy: 7	Acceptability degree: 8	Market barriers: 8	Physical network infrastructure :8
Political integrity in central and regional level: 7	Affordability degree: 8	Relevant markets: 9	Communications infrastructure:8

Political	Social	Economic	Technical
Strong commitment:7	Skill level to engage with grid edge: 6 Structural factors: 7	Economic stability:6	Decentralized flexible Load:7

Source: IEA report 2020 and IENE report 2020-adaptations and compilations for REMTH by author,

The next table shows the REMTH's readiness for Energy transition through adhoc selected by us quantitative indexes.

Table 69. Basic indicators defining the Energy Readiness for Energy Transition of REMTH.

Indicators / scores for REMTH	Energy efficiency	Energy transition readiness	Mean
Growth rates	59,6	------	59,6
Environmental sustainability *	69,3	------	69,3
Energy security	69,7	------	69,7
Energy Investment	------	73,8	73,8
Energy system structure	------	67,5	67,5
Policy and regulation commitment	------	72,5	72,5
Governmental commitment	------	68,4	68,4
Innovative Infrastructure business	------	68,0	56,8
Quality of Human Capital	------	84,8	83,4
Weighted average	66,2	72,5	70,4

Source: World Economic Forum: Annual report for energy 2018 for Greece- Dianeosis energy report 2020. Adaptation and compilation of all data by author.

8.4. Approaching the strategic changes of REMTH's energy model and key-factors impacting on its cost-effective transition

The next important parameter for transition after readiness is the issue of which certain factors influence REMTH's cost effectiveness in order to complete successfully this great energy step. To this aim its energy strategy will have to base on 6 pillars, energy as basis for the new regional growth strategy, greater penetration of RES to energy mix- on/ offshore, saving energy in buildings, smart and upgraded/networked energy infrastructure, smart grids and more energy saving goods and services. These 6 pillars presuppose that the ne REMTH's ES after transition will be, reliable, secure, affordable, and sustainable. Experiences and best practices from across the 273 EU regions can help REMTH to complete the 6 pillars sooner, cheaper and with the less failures. Question, has REMTH the ability-technology, know-how, human quality, financial capital, and equipment- to implement a so large scale project. The answer is yes, under certain preconditions that can be summarized to the next.

- The creation of a new strong and effective adhoc taskforce capable to manage all the relative to transition issues, managerial, technical, technological, and financial.
- The drawing of a smart, flexible, and rolling transition strategy accompanied by master and action plans and clear goals in qualitative, quantitative and time basis.
- The good communication of strategic goals to all citizens of REMTH, in order its society to accept, or reject some of them in early stages so that to be enough time for the proper and adaptations if any by chance failures were ascertained.
- The ensuring all the necessary financial sources in quantitative and time basis. In this process nothing should be left to chance for the future, because a such omission will have great cost for the process.
- The ensuring in advance all the Environmental Impact Studies-EIS for every large scale transition project in order to be avoided strong reactions by local societies during the implementation period.
- The ensuring in advance all the necessary technical, feasibility and cost/benefit studies for every large-scale transition project in order to be avoided strong reactions by total society of REMTH during the implementation periods.
- The capability of regional manufacturing firms to support transition process, since it will bring regional benefits, investment opportunities and enforce employment, beyond that will save import costs and an improved in balance of trade.
- The upgrading of low-carbon technologies in region's energy sector such as, power sector capacity, power sector generation, nonpower sectors, and RES share.

In order to get an outline regarding the percent % of above preconditions for an effective transition towards 2050, we used a questionnaire with open/close questions we addressed to 56 energy opinion leaders of REMTH asking to outline the above and the results are presented to the next table:

Table 70. Factors impact on REMTH's transition success.

Factors impact on REMTH's transition speed and success	Percent %
The creation of a new strong and effective adhoc taskforce	23,3
The drawing of a smart, flexible, and rolling transition strategy	20,2
The good communication of above strategic goals to all citizens of REMTH	16,5

The ensuring all the necessary financial sources and resources	14,8
The ensuring in advance all the Environmental Impact Studies-EIS	12,2
The ensuring in advance all the necessary technical, feasibility and cost/benefit studies	7,6
The capability of regional manufacturing firms to support and be supported by transition process	4,3
The status of low-carbon technologies in REMTH's energy sector	1,1
Total	100,0

Since there is no other well-documented estimation about the factors affecting on energy transition success, fact that should help us and energy decision makers to suggest the best roadmap for the transition to a full decarbonized economy. However, according to such estimations based on field researches, made by the Intergovernmental Panel on Climate Change (IPCC) for other Mediterranean regions having somewhat the same economic and energy structure, we re-estimate indirectly the similar factors for REMTH [21], [23]. The next table presents the key impacts of actions, positive, or negative, of energy transition process during 2021-2050.

Table 71. Indirectly re-estimation of positive/negative impacts of actions towards transition 2021-2050.

Positive impacts	Negative impacts
In environment	
Clearer natural and anthropogenic environment Production systems with almost zero GHG emissions Monuments of nature will be protected forever from whatever pollutions	Maybe some optic or aesthetic pollution to be existed due to huge wind turbines towers
In economy	
Increase of GDP by +1%, beyond the increase owed to other factors Increase of contribution of energy sector to GDP growth rate from 6% today to 8% till 2050 Increase of contribution of energy sector to employment from 5% today to 8% till 2050-maily great increase in indirect and entailed employment	Decrease or stable impact to GDP the first 5 years after the completion of transition projects It is needed greater participation of local societies and innovative actions
In primary sector	
Farmers will enjoy cheaper green energy produced by them or by others obtaining cost competitive advantages Waterland, forests and other protected areas-Natura 2000-will remain protected forever Organic farming will be done easier practice	In initial phases it is probably to exist a reduction of production due to necessary adaptation of farmers to new conditions
Industry-manufacturing companies	
They will enjoy cheaper green energy produced by them or by others gaining cost competitive advantages Some of them will obtain specialization in constructing complete RE systems, or components for them and repairing / maintenance competences Manufacturing will be obliged to become more smart	A retrain of staff of industrial firms will be necessary In initial phases it is probably to exist a reduction of production due to necessary adaptation of staff to new conditions Maybe to be existed workers to resist to such changes
Tourism -trade-services	
They will enjoy cheaper green energy in their operations gaining cost competitive advantages Some of them will gain specialization in such environment	Maybe to be existed workers to resist to such changes
Local technological competitive advantages	
Energy transition will oblige all firms to become more innovative and higher tech oriented Energy transition will oblige all firms to become more energy saving oriented	Maybe to be existed workers to resist to such changes
Regional specialization	
Energy transition will oblige all firms to become more complex increasing their local technological added value	Maybe to be existed workers to resist to such changes
Other generic impacts	
Turning traditional fossil fuel use to new technologies.	Maybe to be existed workers to resist to such changes

Greatly enhancing the sustainability of all energy types. Creating a lower carbon world but ensuring economic growth. Need for power is fulfilled efficiently. Giving new opportunities for high returns, backing the best teams with proven technologies in new applications. A strong focus on ESG as an investment principal, enhances the potential returns.	

Source: AlRafea K at al. 2016, adaptations and compilations by author.

Conclusively, the positive impacts of actions linked with transition are much more than negative ones and this mean that, there will be a strong restructuring of REMTH's energy sector due to transition. The results from our field research among 56 interviewed experts and 4 IPCC field researches for other regions, strongly supported all goals considered as sine qua non for energy upgrading and sustainable development of REMTH. Analyzing the preconditions one by one we see that they indeed support a new energy and growth regional model, new sustainable production pattern consuming less energy/ GDP unique by 60% comparing to today one, more sustainable cities, drastic eradication of energy poverty, creation of smart flexible energy infrastructure, and promotion of sustainable industrialization and innovation.

8.5. Facing REMTH's ES greater variability after transition by estimating the best flexibility level.

Energy decision-makers in order to be mitigated climate change, all ESs must undergo a deep transformation from one that is based on fossil fuels to one that based on RES, enhances its efficiency, pursues electrification to all sectors and increases ES's flexibility. RES and energy efficiency/performance boosted by electrification can provide 90-95% of the necessary reductions in energy related GHG emissions to limiting the rise in temperature to well below 2°C by 2050. Today REMTH's ES variability in average terms is equal to 18,4% of demand and 65,2% to peak demand due to large share of RES (33,4%) in energy mix and the lack of storage systems. This variability is managed successfully by the 2 power units, the NG/CCGT 486 MW, and the hydro 480 MW having storage system 300MW. Since flexibility term is used as an umbrella covering various needs, we clarify the 4 standard categories suggesting in same time and which could be good solution for ensuring the needed flexibility in REMH's ES.

Table 72. Differentiating and categorizing the flexibility term, based on needs.

Flexibility category	Description	Rationalization
For Power	Short term balance between power supply/demand, so that the ES to respond to wide requirement for maintaining the frequency stability	Increased amount of intermittent, weather dependent, power supply-side in the generation mix.
For Energy	Mid to long term balance between energy supply demand, so that the ES to respond to wide requirement for demand scenarios over time	Decreased amount of fuel storage-based energy supply in the energy mix.
For Transfer Capacity	Short to midterm ability to transfer power between supply/demand, where regional limitations may cause bottlenecks resulting in congestion costs	Increased utilization levels, with increased peak demands/supply.
For Voltage	Short term ability to keep the bus voltages within predefined limits and regional requirement.	Increased amount of distributed power generation in the distribution systems, resulting in bi-directional power flows and increased variance of operating scenarios.

Source: IRENA report 2019b

According to IRENA models and after our adaptations and compilations the today and future flexibility providers and enablers in REMTH will be:

Table 73. Sources providing real flexibility and power system flexibility enablers.

Flexibility providers %	**Today providers %**	**Future providers %**
Supply side management	68-72	8-12
Demand side management	13-17	8-12
Transmission-/grid networking systems	8-12	28-32
Storage systems	3-7	48-52
Flexibility enablers %	**Today enablers %**	**Future enablers %**
Power generation system-mix	30-34	26-30
Transmission-/grid networking systems	14-18	20-24
Demand side management	13-17	16-20
Storage systems	2-6	16-20
Distribution system	13-17	14-18
Electric vehicles	8-12	6-1-
Heating/cooling systems in buildings	3-7	4-8
Greenv H2 production systems	68-72	4-8

Source: IRENA report 2019b

Another important issue regarding the flexibility is a method to quantify and calculate it - only one type will be calculated. In order to do it we need the next data and information:

- **Recovery time:** is the time needed to provide flexibility after it has been fully utilized, or the time needed to fully charge the empty energy storage, expressed in minutes- for REMTH is 35 minutes.
- **Power capability to deliver power:** is the size of the flexible active/reactive load, expressed in MW- for REMTH is 560 MW.
- **Response time to peak demand:** is the time of flexibility related to start-up time of 2 power plants, expressed in minutes- for CCGT plant is 35 min and for hydro 54 min.
- **Speed:** is the rate of which the flexibility can be delivered in emergency ramp rate of an expressed in MW/s-for REMTH is 60 MW/s
- **Duration:** is the how long flexibility can be provided, or the time span for overload rating of a component, expressed in minutes- for REMTH is 44,5.
- **Energy merging the power and duration**: is the energy dimensions, expressed in MWh- for REMTH is 735.000 MWh

Based to previous data and using the flexibility metrics “Flexible Power Requirement in MW and Flexible Energy Requirement in MWh, for daily, weekly, monthly timescales and on the adequacy forecast study made by the RAE for the assessment of the power balance of future we result to the next outputs.

Table 74. Estimation of future needed flexibility need and power balance for the peak-load in REMTH

Year	Power balance in MWh/hour	Power balance in MWh/week	Power balance in MWh/month
2020	23,4	122,8	435,2
2030	29,2	159,9	578,1
2040	34,3	191,4	682,7
2050	39,2	228,2	802,5

In conclusion, the increased need for flexibility in the frame of adequacy in power balance for the peak-load in the future REMTH’s ES is considerable, where a large amount of the plannable NG production is foreseen to be phased out. After the above, requirement of a certain degree of operational flexibility for REMTH’s ES with total power 3.367 MW after transition, does not the same as it was before transition. Yet, since the energy mix of REMTH will be significantly variable due to high share of RES- more than 90%, the volatility should be faced by 64,3% from NG/CCGT unit and by 35,7% from hydro unit, eliminating by 95-98% the absurd ups/downs of power supplying. Changes in power demand were largely predictable and generally the volatility was limited, except for a few moments of annual peak load, by 1,2% of operation time. It’s worth to stress the difference between variability and uncertainty of ESs and their different impact on flexibility. Both need flexible reserve units, and flexibility services. Variability is often predictable and often has a known daily periodicity, uncertainty is stochastic and has no known periodicity. Conventionally, the administrator of REMTH’s ES uses detailed analysis of time for uncertainty, 1-5 minutes, and less time for variability, 0,5 -1 hour. It is statistically known that wind energy increases more uncertainty, while solar energy increases more variability. In REMTH’s today ES with a high share of RES 33,4%, three types of variability occur. First, the unpredictable changes in very short periods, consisting of 28,5% of cases observed in the period 2002-2019. Second, the relatively predictable daily variability of solar energy over hours, or the predictable variability of wind over days consisting of 68,6% of cases. Third, relatively unpredictable extreme events such as, the complete lack of sun/wind over a period, which requires large reserves of ES, consisting of 2,9% of cases (RAE, overtime reports). The three types of more frequent flexibility of REMTH’s ES require different approaches.

- **Variability up to 5 min**: requires spin reserve and ancillary services and can be faced it effectively. Such conditions need to increase reserve power as the RES variables develop. When RES share increases by 10,0% in power mix, reserves’ power has to be increased by 3,6%.
- **Variability 6-600 min**: requires power units able to operate/shutdown on a standard hourly schedule and, at the same time, have high load rise/fall. When RES share increases by 10,0% in power mix, reserves’ power has to be increased by 7,3%.
- **Long term variability**: it only addressed through long-term replacement reserve units. The technical tools that can provide flexibility in REEMTH’s ES have different capabilities in terms of the three variability classes.
- **Komotini NG/CCGT power unit**: can serve high short-term flexibility, as it has short start times and ups/downs. However, due to its increased operation cost, it is not suitable for providing multi-hours of flexibility.
- **Nestos’ hydro power unit**: having a storage system of 370 MW is suitable for reducing peak loads facilitating meeting the requirements of long hours flexibility.

The next figure gives a clear image regarding the REMTH’s ES flexibility and how the Komotini NG/CCGT unit cope with variability of power supply with the RES share 33,2%.

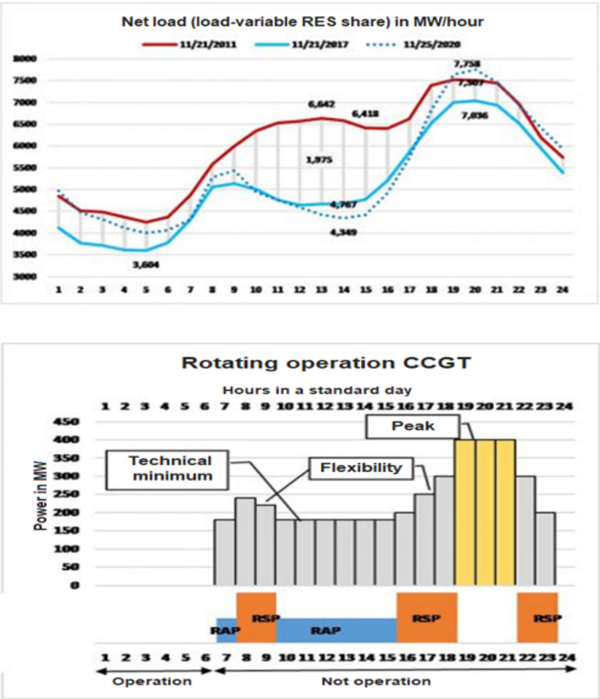


Fig. 28. Cyclical operation of Komotini NG/ CCGT unit and REMTHs ES flexibility - Net load (load-variable RES share) in MW/ h-.Source: RAE reports 2002-2020, DEH reports 2002-2020

Conclusively, the estimation of necessary power of reserve units has great interest since it can help experts to predict with more accuracy future technical operating parameters such as ups/downs rates, minimum operating power, synchronization and shutdown time, minimum on/off time and its capabilities for reserve services automatically, handled by ES management.

8.6. Field research and statistical analysis about REMTH's societal views for transition.

In our effort to form a clear picture regarding the REMTH's societal views for the transition, as it is analyzed to previous, we chose to write-down the views of some REMTH's opinion leaders being experts in all energy issues via adhoc interviews. So, we formed a questionnaire and we addressed to 56 opinion leaders of REMTH interviewing them. The interviews were conducted with all type of questions, over a period of six months in 2019/1st semester and their profile is presented to the next table:

Table 75. Characteristics of the respondents.

Characteristics of the respondents	**Number**	**Percentage %**
Male	48	85,7
Female	8	14,3
Age 25-40	12	21,4
Age 41-60	28	50,0
Age 61-70	16	28,6
Education High school	2	3,6
Education Graduate	43	76,8
Education Postgraduate-MA, MSc, PhD	11	19,6
Employees in energy sector	29	51,8
Employees in environment sector	7	12,5
Employees in manufacturing sector	12	21,4
Employees in other sectors	6	10,7
Researchers /Academics	2	3,6
More favor in rapid energy transition	37	66,0
Less favor in rapid energy transition	19	34,0
Be well informed about energy transition	32	57,1
Be moderate informed about energy transition	23	41,1
Be less informed about energy transition	1	1,8
More favor in Photovoltaic	26	46,4
More favor in wind turbines	26	46,4
Be reserved about both, P/V and W/T	4	7,2
Permanent residence in cities	47	84,0
Permanent residence in villages	9	16,0
Total	**56**	**100,0**

For statistical analysis of 56 respondents, it is used the "Equation of Measures Model-EMM" that, exempt others, can measure the relations between latent and measurable variables-respondents answers. The questionnaire was focused to 8 certain fields that were summarized as answers to table below [114a], [121]:

Table 76. Initial statistical analysis of answers of REMTHS experts regarding the energy transition.

Steps	**Certain activities toward the energy transition in REMTH**	**Variable**	**Number**	**%**
1	The necessity for a new smart and digitized regional energy organizational structure	NOrg	13	31,7
2	Ensuring the necessary capital to finance the planning activities for a cost effective transition	CAP	34	82,9
3	A smart campaign to region for a grater societal acceptance of needed RES investments	CHAMP	7	9,7
4	Electrification of transportation, heating and cooling will contribute: ELECTR	ELECTR	25	61,0
5	The potentiality for increased RES penetration and choosing the best power generation mix	RES	35	85,4
6	Promoting actions for the best energy efficiency and saving in	SAVE	25	61,0

Steps	Certain activities toward the energy transition in REMTH	Variable	Number	%
	buildings, industry, services			
7	Promoting smart macro/micro grids and electrometers	GRID	14	34,1
8	Promoting cost effective storage systems	STORE	21	51,2

To check the reliability and validity of answers and for further statistical analysis of above data, we used the Exploratory and Confirmatory Factor Analysis-ECFA. The relationships between the variables were tested using the "Structural Equation Modeling- SEM. The SEM running is resulted to outputs below:

$$\begin{aligned} \mathrm{EnTr} = {} & 0{,}3\ \mathrm{NOrg} + 0{,}11\ \mathrm{CAP} + 0{,}03\ \mathrm{CHAMP} \\ & + 0{,}26\ \mathrm{ELECTR} + 0{,}21\ \mathrm{RES} + 0{,}15\ \mathrm{SAVE} \\ & + 0{,}08\ \mathrm{GRID} + 0{,}13\ \mathrm{STORE} + u \end{aligned}$$

The above equation helped us to find which will have to be the necessary steps and activities for a successful and effective transition, since answers consist of good guide. Continuing the analysis of above data and making the needed statistical tests we result to the below tables.

Table 77. Checking the model's suitability by Confirmatory Factor Analysis of variables impacting the transition success.

Variable	Prices/values
Chi-Square	103,345
Degrees of freedom	32,000
Chi-square to degrees of freedom ratio (X^2/df)	3,229
Probability level	0,000
Root Mean Square of Approximation (RMSEA	0,037
Goodness of Fit Index (GFI)	0,944
Adjusted Goodness of Fit Index (AGFI)	0,915
Normed Fit Index (NFI)	0,913
Incremental Fit Index (IFI)	0,939
Tucker-Lewis coefficient (TLI)	0,905
Comparative Fit Index (CFI)	0,915
Akaike's Information Criterion (AIC)	299,498
Expected Cross-Validation Index (ECVI)	0,445

Table 78. Exploratory Factor Analysis: Kaiser-Meyer-Olkin Measure of Sampling Adequacy-KMO.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy-KMO		0,904
Bartlett's Test of Sphericity	Chi-Square	54,46
Bartlett's Test of Sphericity	df	97,0
Bartlett's Test of Sphericity	Sig	0,001

Our research effort combines the evaluation of nature and the relevant strategic policy conditions in the field of energy as well as the proposals for the revision or drafting of new specific and general projects. The above results prove that the answers of 56 opinion leaders have a rationalism and can consists of key elements for the factors that will influence both, how successful and cost-effective can be the energy transition in REMTH and they will be formed the guide to the step-by-step transition plan.

8.7. Top P/V and W/T technology trends for the future and the potentiality to be introduced to REMTH.

The energy demand will increase, mainly for electricity. From 1991 till 2020, electricity consumption increased in Greece by 128% and in REMTH by 87% and this trend seems continue in the future. So, ES must be able to produce enough electricity to 100% of consumption-even in on peak demand. At the same time, to address climate deterioration issue the installation of cleaner sources such as P/V and Wind/Turbines has been adopted as the best solution. Because of higher electricity prices from solar P/V system developers are more interested in the LCOE question.

If the electricity OPEX from PV minus Fit-in Tarif price is lower than electricity from fossil fuels, then PV attracts many investments. Solar provides a good return on investment as well as protecting the environment. The data from 2018-2021 were encouraging since they showed that LCOE index of utility-scale and commercial PV is already lower than fossil fuels. Toward 2030 PV-LCOE is expected to decrease, even more due to declining PV modules prices and higher efficiency modules. Mono-wafer PV tech manufacturers adopt bigger wafer sizes to increase the power output from a single module. But the larger wafer requires a degree of renovation in the production line, which could be difficult for manufacturers to do it soon. Other innovation, after PERC, is likely to become Tunnel Oxide Passivated Contact Technology which uses a sophisticated passivation structure and promises to improve efficiency more than 20%. This technology will be combined with the n-type mono-wafer one to achieve max efficiency. But the most notable change would be the bifacial module cells that could be used with a transparent back sheet. They can also be used in a mono facial module with a design that would reflect the light from a white back sheet to the cell. Bifacial cells could be made from different technologies, from PERC to HJT and should have great potential to become vital on utility-scale PV power stations. In additional to previous, inverters will consist of the future crucial component of the PVs, converting the DC current from PV modules to AC one to feed the network and to be used in households. Smart inverters are enablers not only monitoring but also diagnostics of the PV system.

The trends in W/T design refer to increase tower height, blade length influencing the rotor diameter and load capacity (IEA 2013 and 2020). W/T have increased in height/rotor diameter faster than their electrical abilities. The height of tower and the length of blades increased their CF at the same time, wind speed. The above have led and will continue to lead to rotors designed for high capacity even with low-speed winds. The high towers, long blades and generator's size with higher CFs allow the installation of W/T in low-speed wind areas. It occurs closer to consumption centers than the best wind spots needed more expensive transmission infrastructure (Kwakkel, J. H. at al, 2014, 'Visualizing geo-spatial data in science, technology and innovation', pp. 67–81). Advances in blade design, using new lighter materials will contribute to increase W/T efficiency compared to its named installed capacity (IEA 2013).

Wind generation equipment can be divided into 4 types, wind energy capture, location, capacity, electricity generation type and control system. According to axis, wind energy capture is formed as, horizontal, vertical, 1-blade, 2-blades, 3-blades, multiblade. According to location formed as, on/offshore. According to capacity as, industrial, small, medium, mini. and micro generators. According to generator type as synchronous asynchronous. According to control system formed as blade pitch control and stall. Top patent depositors in wind high-techs are, General Electric (575), Mitsubishi (560), Wooden Aloys (341), Siemens (253), Vestas Wind Systems (248), Hitachi(139), Samsung (111), Hyundai (74), Repair Systems(72) and NTN (69)-total 2442 patents till end 2020. (Falani S at al: Trends in the technological development of wind energy generation 2020). Based on above we can conclude:

- Smart energy technology solutions can be provided by RES with higher performance and lower CAPEX/ MWh and OPEX/MWh. According to my point of view, REMTH has all the necessary resources not only to upgrade its energy system, climate, and environment through transition to an economy with zero CO2 emissions, but it is capable to successfully implement them.
- The future of RES is so favoring so that REMTH to do ambitious plans for a cost-effective transition. The new general and adhoc conditions trends and breakthroughs in P/V-W/T systems matching to REMTH's competences [77], [111], [117], [118].
- REMTH's traditional energy companies will diversify their production in order to include RES at the forefront. Solar and wind power will become more affordable and cost-effective.
- Increased demand for everyday solar and wind technology products as spare and maintenance parts will be happen in Greece and REMTH.

The adhoc advance technological developments for RES, matching to REMTH's production and energy systems are:

Table 79. Top clean energy technology trends for P/V, W/T matched to REMTH.

Top clean energy technology trends for PV, WP, storage systems	**Solar and storage trends**	**Wind parks trends**
Solar energy installations to grow by at least 30%	Buildings will be designed to be carbon-negative	Increased efficiency thanks to new shape of wings
Rapid solar technology innovation continues despite shrinking PV system costs	Homes of the future will have two batteries in every garage	Rapid wind offshore technology innovation continues despite the costs remain great
Rapid wind offshore technology innovation continues despite the costs remain great	Dual battery-other technology storage systems	Even more higher towers increasing their ability to exploit lower air speeds
Exponential growth for production and using hydrogen	The module-level power electronics duopoly will continue	Using drones for wind turbines inspection
Recycling becomes a priority for companies and governments globally	Skill levels for solar and storage contractors will increase	Innovative wind turbine blade that has led to an increase in energy capture by more than 12%
Hydrogen planes	Rooftop solar systems should be oversized	Broadening their power from 50 KW to 20 PW
Solar-powered desalination systems	Customer service and warranties are key battery system selection criteria	Greater using of computational fluid dynamics to develop smart simulators for Wind Farms which help wind farm operators minimize the impact of turbine wake effects by investigate plant performance under a full range of atmospheric conditions.
Satellite mapping as climate adaptation infrastructure	EV chargers will be common options for new solar and battery installations	Wind turbines are increasingly cost-effective. more reliable, and have scaled up in size to multi-megawatt power ratings
Smart vertical farmland and forestry tracking as climate adaptation infrastructure	Efficiency and performance of solar systems-PV will increase by 20-25%	Utilizing the controllable grid interface test systems, which reduce wind turbine certification testing times and costs while providing system engineers with a better understand of how wind turbines, photovoltaic inverters, and energy storage systems react to disturbances on the electric power system.
Chemical plastics recycling	PV parks will have to link with pumped-hydro storage systems	
Lab-grown meat		
Carbon Engineering's Tech Will Suck Carbon from the Sky		

Source: World Economic Forum: Annual report for energy 2018 for Greece- Dianeosis energy report 2020. Adaptation and compilation of all data by author.

8.8. Putting transition in practice: the ten energy transition steps.

Considering that, REMTH is a rather poor region, but has significant potential for its energy sources and system upgrading and that the region must be adapted to new energy directives of EU, we present the necessary steps.

Firstly, the general steps or transition principles:

- The REMTH's energy transition is something more than decarbonization. Region's successful transition needs to balance the energy triangle, environmental sustainability, energy security/reliability and economic development.
- The climate deterioration warns and clarifies to all the urgency of the situation.
- The transition is not just switching fossil fuels to RES and existed cars to EVs.
- Since the transition is a very complex issue, many solutions should be suggested. Some claim the solution is the increasing energy efficiency since only 33% of primary energy is converted into useful one, the remaining 67% is lost because of the low efficiency in electricity production, transport, and buildings heating/cooling.
- A triple-holders approach is needed even in regional level for a successful transition, public sector, private one and local societies. All together can develop a mix of good solutions being technically, economically, and socially viable.

Secondly, the adhoc and practical steps of transition should be:

Step 1: Reorganization the structure REMTH's ES through digitizing and mapping a clear plan of transition supported by all stakeholders. It means the formation of a new flexible regulatory/managerial environment to welcome and boost new institutions and RES technologies. For REMTH the regulatory framework has to become more flexible and attractive for further penetration of new technology RES so that to cover the 90-95% of electricity demand till 2050. Considering the above, it is necessary to be redesigned the REMTH's energy structure with the establishment of an adhoc **"**Regional Energy Coordination Organization-RECO", in order to be able to cope with its new responsibilities. RECO will have to be a flexible, decisive, and visionary entity in order it can quickly respond to new challenges emerged to new energy landscape. The high complexity of even the regional ES requires the constant redefinition of the role of RECO and the way in which new challenges are approached and redefined. Smart regional ES means digital maturity of all its components in order to be able to be adapted to the 4th Industrial Revolution rules. [109], In conclusion, the smart re-organizational structure has to support REMTH's ES, coping with the 10 technoeconomic challenges:

- Withdrawal of lignite/oil thermal plants till 2025, even those using NG till 2045.
- Wind and Solar energy sources will supply greater than 90% of total power produced till 2050.
- Production green H2 by electrolysis, using power coming from offshore RES and using it as storage system and as fuel for power production till 2030.
- Replace almost the 100% of conventional vehicles with electric ones till 2045-EV's.
- Creation of dynamic and cost-effective storage systems with fast downloading ability, based on batteries and hydro-pumped systems at least 1.850 MW till 2040.
- New smart digitized macro/microgrids for power transmission/distribution.
- Well-dispersed onshore/offshore P/V-W/T parks using new geospatial tools.
- Introduction of dynamic idle power management tool with STATCOM, modern capacitors making regional ES more flexible and cost-effective.
- Introduction of smart 2ways Demand Management System for the regional microgrids and telemetering for all end users.
- The basic conclusions are:
  1. The transition is a long process that requires the commitment of all actors
  2. Commitment ensures that there will be continuity in the process
  3. Practical design for the Clean Energy Transition Plan is an important first step for shaping the organizational basis of the transition process. Duration of step: 24 months and estimated cost: € 2.000.000 [114], [120].

Step 2: Finding the necessary capital resources to finance the planning activities for a cost- effective transition. In addition to national /regional capital resources which are limited, more important are the European ones available to support projects focused on a just and efficient transition. These are 9 key-funds, Just Transition Fund (JTF), Invest-EU Economic Recovery Plan (ERP), Innovation Fund (INNOVF), Financing Activities for Climate Fund (FACF), Mechanism Connecting Europe's Modernization and the adhoc projects (LIFE) and HORIZON-2020. All funds are flexible to their fast decision process, fact very useful for easy transition. The total necessary capital of complete transition for the whole country estimated to, € 33 bil to 2030 and € 87 billion till 2050. The corresponding amounts for REMTH are € 8,4 and € 3,3 billion. The distribution of these € 3,3 billion till 2030 according to:

1. The initial approaches of the responsible authorities
2. The views of 56 energy opinion leaders interviewed
3. The necessary adaptations and compilations made by us, are given in the table 80.

Duration of step: 18 months and estimated cost: € 1.000.000.

Remark:
There is a lack of realistic forecasting for investments in new ITC technologies, Cloud, RFID, AI, Blockchain, Robotics/Mechatronics. Because of the high dependence of the financing digitization of ES from public resources, the low relationship of energy sector with universities, the lack of incentives in attracting high value-added energy FDIs, are the key factors of REMTH's ES backwardness. There is already a starting point, the 'Sustainability Charter' adopted by the Summit of Rectors since 2011 for tight cooperation of energy sector with universities

Step 3: Launching a smart campaign for a well-communication and greater societal acceptance of transition viable goals. Transition process will be based, by 35% to over-doubling of RES share in power mix, by 12% to energy saving/nullifying losses in buildings, 38% by transports through its electrification, 5% by industry through robotization and increased performance and by 10% to the other lees important factors. All these challenging goals require acceptance by the local societies in order to be reconciled conflicting interests. Because of importance of previous, it is considered necessary to be measured the social acceptance by REMTH's citizens.[121], [121a]. Our research showed that the most important parameters for the transition were the great acceptance of RES penetration in their area impacting positively on environment and economy and the fear for negative impacts due to lack of information, or even ignorance [121], [121a].

Table 80. Resources and sources for funding energy transition activities.

Step of energy transition /budgeting in mill €	**Initial estimated budgeting-€ mil**	**Financial sources**
The necessity for a new smart and digitized regional energy organizational structure	20,0	NSRD
Ensuring the necessary capital to finance the planning activities for a cost-effective transition	0,0	JTF, CAF, INNOVAF, Private funds, NSRD, Public resources
A smart campaign to region for a grater societal acceptance of needed RES investments	2,0	JTF
Electrification of transportation, heating and cooling will contribute	660,0	JTF, CAF, INNOVAF, LIFE, HORIZON, Private funds, NSRD, Public resources
New technology RES installation and choosing the best power generation mix	1.300,0	JTF, CAF, INNOVAF, LIFE, HORIZON, Private funds, NSRD, Public resources
New offshore wind parks in Thracian Sea	308	JTF, CAF, INNOVAF, LIFE, HORIZON, Private funds, NSRD, Public resources
Promoting actions for the best energy efficiency and saving in buildings, industry, services	470,0	JTF, CAF, INNOVAF, LIFE, HORIZON, Private funds, NSRD, Public resources
Promoting smart macro/micro grids and electrometers	210,0	JTF, CAF, INNOVAF, HORIZON
Promoting cost effective storage systems and innovations	330,0	JTF, CAF, INNOVAF, HORIZON
Total	**3.300,0**	**All funds**

Sources: NPEC report 2020-2050 (2020)-NEEI report 2020- National Regulator of Energy report 2020-adaptations and compilation in regional level by author.

In this framework, through a questionnaire with all type of questions we achieved to collect 56 answers and through descriptive statistical analysis, we could shape a well-documented picture regarding the views of regional societies about the transition and its impacts.

Table 81. Statistical analysis of the field research among 56 opinion leaders of REMTH (Males 37, Females 19).

Feature	**Number or %**	**Number or %**	**Number or %**	**Number or %**
Age	28-40	41-60	61-67	67>
Percentage %	31,9	39,0	22,1	9,0
Educational level	Graduate	Postgraduate	PhD	00
Percentage %	47,3	49,1	3,6	00
Awareness	Least	Little	Good	Very good
Percentage %	2,0	5,6	65,2	27,2
Whether RES save energy	Very little	Little	Much	Very much
Percentage %	1,0	11,8	76,2	11,0
Benefits more than costs	No	Yes, but very little	Yes, and much	Yes, and very much
Percentage %	0,0	10,4	75,0	14,6
Which are the negative impacts on environment	Optic	Aesthetic	Heavy noise	Kill the birds
Percentage %	45,0	12,5	15,0	27,5
Which RES consider as the most polluters	P/V	W/T	Hydropower	Biomass
Percentage %	21,2	46,8	27,5	4,5
Acceptance of RES and area of living	Rural areas >500m height	Agriculture <500m height	Semi urban	Pure urban
Percentage %	32,0	12,4	18,4	37,8

Table 82. Social acceptance of transition actions/RES/ investments in REMTH.

Activities toward the energy transition	Percent % with positive view
Installation of PV parks in fertile farmland	13
Installation of PV parks in non-fertile farmland	51
Installation of wind parks in height greater than 1000 m	17
Installation of wind parks in height lower than 1000 m	16
What causes the greater fear	7
Optic pollution	6
Esthetic pollution	5
Damages on fauna and flora	5

The statistical analysis showed that:

1. Well-educated people have a good level of information about the transition issues
2. More alarm causes wind parks
3. Regardless the educational level, there is fewer information about Hydroelectric, geothermal and biomass plants.

The most important advantages caused by transition are, the protection of environment, the strengthening of local economy and the green sustainable development. People living in rural and semi-urban areas are generally more tolerant of installing RES in their areas than residents of urban areas. There is a significant positive correlation equal to r=069-0,86 between the acceptance of RES with, education level r=0,76, area of living r=0,65 and the gender, males r=0,71 females r=0,83. Running data by Logit Model we can determine useful indicators. The most important variables in transition process seem to be,

1. The economic and environmental costs and benefits
2. The type of RES technology will be used and the method it will be carried out in practice and
3. The degree of how much the GHG emissions will be reduced.
4. W/T seem to divide public opinion, especially in the first years of their installation, reporting as problems their noises and optic disturbance they bring about in combination with some minor effects on the local flora and fauna.

All the above mean that it is needed to be launched a smart campaign in the region so that local societies to be informed well for the real positive/negative impacts of RES and their role in the transition process. Duration: 24 months and cost: € 1.000.000

Step 4: Estimating and defining the optimal share of RES in power mix with the least CO2 emissions. The plausible need for increase of electricity production due to predicted increasing of demand by 2,2%/year till 2050 leads to the max utilization of the available natural energy sources of REMTH-sun, wind, hydro, geothermal, biofuels. From the total natural energy potential of Greece/REMTH, it is estimated that only 18,5% should be exploited, or 10,0-12 GW/1,2 GW corresponding, with existed technology (Levelized Carrying Capacity-LCC-2019)..According to global literature, the most advantageous option for a competitive regional ES and for power-consumers themselves, are 100% RES-the same for REMTH [1], [26], [49], [51], [67], [113], [116]. Many experts estimate that, RES should capture in REMTH a share of 85-95% to power mix till 2050. Yet, great energy savings can reach to 65% of today consumption, meaning for REMTH an entailed power contribution equal to 540 GWh, or saving € 27.000.000 annually (CRES 2018) Reports of "European Roadmap for Energy and Climate towards 2050-EREC-2050" (2019-2020) analyzes different scenarios for an optimal ES and shows that, energy saved is that never produced, and this practice is even better solution for future decarbonization than RES, since there is not any cost and GHG emissions are 100% zero. In any case, RES will continue to play the key-role in transition and are the absolute future of clear energy. From five alternative scenarios suggested by EREC-2050 for 273 EU regions, Increased Energy Efficiency, Differentiated Technologies, Increased Penetration of RES (at a rate of 85-100%), Delayed Implementation of CCS, and Low Compact Scenario , the best one for REMTH is Increased Penetration of RES at a rate of 85-95%-it is fitted very well. European Wind Energy Union (EWEA) emphasizes to the RES increased share reaching 85-95% in electricity mix till 2050, considering it as the most cost-effective and sustainable option. EWEA claims that, for every area, there is an optimal share in % of P/V, W/T, Hydro power in MW. For REMTH, using the tools of SCBA/multiple regression and, taking in account 6 variables, X1=carrying real capacity of RES, X2=speed of wind, X3= duration of wind with certain speed, X4=shiny hours/year, X5=quantity of reserved water in M3 and X6=existed power in MW, we result to an optimal share towards 2050: W/T= 41,4%, P/V=30,6, Hydro=11%, other RES=10%, green H2 7%. The table below presents the above variables elaborated by SCBA and then by multiple regression leading us to choose the best energy mix for the best transition roadmap.

Table 83. The variables, values and indicators used by SCBA tool-prices and values are in average terms.

Costs/ type of RES*	W/T onshore	P/V onshore	W/T offshore	P/V offshore	Geothe-rmal	Biomass	Hydro	Mix H2/NG
Lifetime	25	25	25	25	30	30	45	20
CAPEX 000 €/MW	1.385	1.023	1.876	1.435	1.760	1.360	2.764	2.345
OPEX €/MWh	24,4	28,2	30,5	33,7	48,4	38,4	25,8	42,2
Financial Analyses								
Financial cost/MW own borrowed money €/MW	83,1	60,2	112,5	86,1	105,6	81,5	165,8	146,2
Socioeconomic cost €/MW	75,5	58,6	109,7	84,4	103,2	79,2	154,2	144,8

Sensitivity analysis for how €/MWh impacts on demand as %	5,6	5,6	5,6	5,6	5,6	5,6	5,6	5,6
Risk for investments as %	22,2	16,9	24,5	21,3	11,1	10,4	16,8	6,9
Economic Analysis								
External costs as €/MWh	0,05	0,09	0,03	0,03	0,01	0,02	0,14	0,05
Levelized cost as €/MWh	41,5	43,3	44,6	50,1	55,4	46,2	42,2	53,2
Gap between wholesale/retail prices %	11,4	11,9	12,4	12,8	14,4	15,4	11,4	11,4
Calculation of IRR	12,3	11,6	12,5	11,5	16,4	13,2	10,3	16,2
Analysis of multiple criteria								
Probability risk analysis for whole transition project as %	22,3	23,5	26,2	24,6	16,4	15,6	24,9	22,6
Suppositive development scenario to energy transition as probability %	77,7	76,5	73,8	75,4	83,6	84,4	73,1	87,4
Financial indicators								
Energy Return on Investment EROI=Energy inputs/energy outputs	8,6	9,7	8,1	9,1	12,4	14,8	8,4	18,3
Operation asset as % of total asset	14,3	14,0	11,3	10,4	26,8	28,3	18,2	32,3
Special Liquide Ratio	8,5	7,4	7,4	8,2	2,6	3,2	4,3	6,4
Debt-equity ratio	0,86	0,85	0,88	0,86	0,92	0,90	0,82	0,87
Long term dept	59,4	64,2	62,3	61,2	60,3	56,3	64,8	76,4
Short term dept	40,6	33,8	37,7	38,8	39,7	43,7	45,2	23,6
Return on Equity ROE	8,8	10,3	9,4	10,3	13,4	16,5	11,2	17,6

Source: RAE adhoc reports 2001 to 2021-IENE reports 2010 to 2020-IEA overtime reports- adaptations, compilations, and calculations by author.

* In the above economic analysis, we used the new approach in the financial analysis based on comparisons and measurements and using data of the current accounting year.

The type of RES technology will be: onshore W/T=45% with CF=50%, offshore W/T=55% with CF=55%, onshore P/V=60% with CF=50%,, offshore 40% with CF=50%,, geothermal =100% high performance with CF=90%, biomass/biofuels=100% with CF=80%,. Citizens will be aware that, in order to be achieved the above goals the below actions and activities will have to be taken place in their residential areas.

- No power production technology is 100% neutral in relation to environment-aesthetic, or acoustic noises, but in permissible degree.
- REMTH is endowed by abundant of wind, shine and geothermal.
- RES are clean energy by 95% technologies, cheap/MWh, reliable/resilient combined by storage systems.

The above basic principles ruling the increased penetration of RES in power mix in REMTH are given to the table below.

Table 84. Principles ruling the increased penetration of RES in power mix in REMTH.

Category of Criteria	**Description**	**Gravity index %**
Economic	• Production costs – minimization. • Investment costs-optimal. • Investment repayment rate-optimal payback period. • Social Cost Benefit Analysis. • The investment risk-the potential minimum. • The possibility of a constant profit rate-best profitability. • The cost of other fossil fuels-benchmarking.	30

	• Economic growth-maximization. • Financial contribution to the local economy – maximization. • GDP growth index at regional level – maximization. • Sources of financing-more and easy funding. • Cost of land-comparatively the optimal.	
Energy	• Stability and safety in energy supply, optimal availability of fuels. • The best RES potential development -sunny, air, geothermal, biomass. • Power plants efficiency, the best performance. • Energy payback period: ratio of energy produced throughout the life of an installation to the energy required to build and operate the project: the minimum. • Quantity of conventional fuels saved by developing alternative sources is measured in tons of oil equivalent - the optimal. • Differentiation of production- the optimal. • Possibility of parallel use of this produced energy or utilization of the discarded. part of it in district heating units-the optimal.	28
Environmental	• Environmental burden from GHG emissions min kg GHG / kwh for life cycle. • Ability to reduce GHG emissions. • Impact on the aesthetics of the landscape-min. • Effects on biodiversity, local flora and fauna -ecological stability. • Possible status of protection of the installation area. • Land needed as index for land using for RES installation- best index of kWh, (Km2 / kwh)). • Impact on agriculture, livestock or tourism-the min potential. • Noise generated-min. • Impact on water resources-min. • Consequences of possible entry of waste or waste-min. • Possibilities of utilization of the discarded materials-the best. • Effects from the creation of accompanying projects-the optimal. • Time and cost of restoring the environment after the operation of the unit.	22
Social -political	• International commitments of the country and obligation to comply with European energy policy-the optimal. • Possibility of dependence on imported energy sources- the optimal. • Quality of relations with neighboring countries - the optimal. • Opportunities for infrastructure development - the optimal. • Decentralization of production - the optimal. • Creating new jobs-best price for the index new full time jobs / MWh in life cycle. • Compatibility with the activities of the area-the optimal. • Social acceptance --the optimal. • Existence of local interest groups and their degree of intervention. • Local Community Sensitizing Degree-the best. • Adhoc tax for local communities -the best Impacts on health, safety and quality of life of local communities.	10
Technological	• Reliability of applied technology-the best Security-the optimal. • Technology maturity-the optimal. • Network stability and ability to respond to demand shifts-the best. • Possibility of future development-the optimal. • Time of future devaluation of the applied technology-the optimal. • Compatibility with local capabilities-the optimal.	10
Total		100

Source: NPEC report 2020-2050 (2020)-NEEI report 2020- National Regulator of Energy report 2020-adaptations and compilation in regional level by author.

Duration: 24 months and cost: € 1.000.000.

Step 5: Promoting electrification in transport, industry, and buildings. The acceleration of electrification in transport means and cooling/heating of buildings of the region with the necessary power coming from new technology and high-performance RES and least variability through storage systems-batteries, hydro-pumped and green H2. Old technology vehicles need to be replaced by more sustainable ones, with widely available green alternatives. In order to be done it, generous incentives are necessary to trigger and promote electrification creating a new transport system. Innovation and digitalization of REMTH's transport system will shape a new landscape in the way the future passengers and goods will be transferred in/out of REMTH. Passengers will be able to purchase tickets for multimodal travel system saving money, time, and energy. Also, the goods should switch seamlessly between different means of transport. Cloud, Blockchain, Data analytics, Internet of Thinks (IoT) and Artificial Intelligence (IT) will enable REMTH's innovative production system to construct UAV's facilitating the fast and safe transfer of people and goods. Since the new transport system will be based on electricity, it is suggested for REMTH to focus initially on the fast increase of RES share in its power mix. In any case, it has to strengthen and develop its innovative construction capacity in the electric sectors, where has already some competitive advantages, due to existing expertise, know-how, and Polytechnic Schools. The proposed framework of our electrification plan presupposes:

-Strong state incentives to craft /industrial firms with relevant know-how and construction capabilities in order to direct invest in development, or improve electrical appliances related to transport electrification. Yet, State incentives will be needed for developing new innovative technologies concern energy saving systems. Below is a table with the proposed categories of electrification, energy saving and new RES technologies where, based on suggestions of NPEC-2019/2020 for Greece as a whole, we made the necessary adhoc adaptations/compilations in order to be proper for REMTH. [14], [63], [103], [108], [111], [116].

Table 85. Proposed indicative ideas of electrification, energy saving systems and RES technologies-2050.

Energy production consumption	**Necessary systems, equipment**	**Institutional and economic measures**	**Growth opportunities and manufacturing relative products/ services**
Electrification of road transport Till 2030 the 33% of EV will be electric. Transportation system till 2050 will be 90-95% electrified, smart, sustainable with high-speed connection	Electric Vehicles for passengers and goods -EV	Measures for the launching of EV and charging infrastructure.	Budgeting: € 340 mil (estimation) EV, motorcycles, bicycles, and adhoc small vehicles for green cities
30% of industrial vehicles will be electric	Industrial EV	Financial incentives for initial I-EV promotion	Batteries, chargers, chargers, and transaction management systems
15% of power generated by RES	Smart storage systems and chargers	Completion of an attractive institutional framework	New organizational structure
Heating/cooling electrification			Budgeting: € 402 mil (estimation)
Thanks to such systems 2 cities of REMTH will be completely green	Heat pumps, dehydration systems, MIS	Energy saving, high performance, no emissions	Development of building insulation products, high efficiency heat pumps, sensors, S/W and MIS
In-home and in service firms power production >400KW			Budgeting: € 1,25 bil (estimation)
	New RES and storage systems, MIS for power production/consumption	Incentives for new systems, simplification of approvements & licensing-making process and land planning	Construction of components of P/V and wind systems, batteries, MIS for energy, smart electrometers
	Energy markets	Attractive institutional environment for new RES and storage systems	Participating to national and European energy markets
		Potentiality for interregional energy exchanges	New organizational structure
Large scale power generation > 400 KW)			Budgeting: € 680 mil (estimation)
	New RES and storage systems, MIS for power production/consumption	Incentives for new systems, simplification of approvements & licensing-making process and land planning	Construction of components of P/V and wind systems, batteries, MIS for energy, smart electrometers
	Energy markets	Attractive institutional environment for new RES and storage systems	Participating to national and European energy markets
		Potentiality for interregional energy exchanges	New organizational structure
Total budget in €			2.332.000.000

Source: NPEC report 2020-2050 (2020)-NEEI report 2020- National Regulator of Energy report 2020-adaptations and compilation in regional level by author.

Duration: 24 months and cost: € 1.000.000.

Step 6: Promoting energy storage systems (ESS) in all sectors. ESS can be applied to REMTH's ES in all 5 stages, power generation, transmission, electricity transformers, macro, and micro transmission/distribution for supplying clients, even to be coped with on-peak loads, due to high share of RES. REMTH through ESS can become a power exporter region since through such technologies can ensure at least 50% of today average demand without any loss, that equals to 1.220 MWh, meaning an additional benefit of € 55.00.000/year, or € 1.650.000.000 till 2050. Further, the investments in ESS, will upgrade total Greece/REMTH's ESs and their geopolitical and geoeconomics role in SE Europe. The proposed ESS are divided into three types:

1. The connected ones with specific hybrid infrastructure,
2. The exclusively store and trade energy in the energy markets,
3. The exclusively ESS can smooth the load curves and the trading conditions.

The key positive effects of ESS are, optimal flexibility ratio leading to better controlled stochasticity, grid stability, ancillary stock, and regulatory control (Electric Energy Storage, White Paper, IEC, Geneve, 2021). Regarding the role of NG as bridge fuel till 2045, it will support the optimal balance between power supply/demand along with ESS and also will stabilize the investment cycle of the power units, since as, "the more share % of PV/ WT to REMTH's energy mix, the more uneasy PV/WT curves of load will match. The ESS in REMTH will take place by 5 forms within a period of 25 years, as these are given to table below [20], [25], [27], [31], [55], [103].

Each of above storage technologies has some unique features that make it suitable for a specific location. These unique features help us to suggest as the best technology for the REMTH through an unofficial benchmarking system based on 5 criteria.

Table 86. Technologies of ESS fitted to REMTH's energy system for the period 2021-2045.

Electric	Electrochemical	Chemical	Thermal	Mechanical
ES based on condensers	Batteries lithium	Green H2 storage	Sensible TES	Hydro-Pumped
Superconducting magnetic ES	Batteries NaS	Synthetic NG	Latent Heat ES	Compresses air ES
	Batteries PbO2 Batteries NiCd Batteries Flow technique	Fuel cell technique	Thermochemical ES	Flywheels_ES

Source: NPEC report 2020-2050 (2020)-NEEI report 2020- National Regulator of Energy report 2020-adaptations and compilation in regional level by author.

Table 87. Evaluation of above Energy Storage Systems based on technical, economic, and environmental characteristics.

ES technology	Density of ES MWh/ton	Regaining efficiency %	Availability and technology maturity	Capital cost €/KW	Advantages
Electric ES	300	85-98	Immature	600	High performance, great lifetime
Electric SMES					
Electrochemical NiCd	70	65-95	Available	500	High power and performance
Electrochemical Li	115	95-100	Available	200	High power and performance
Electrochemical PbCd	35	75-80	Available	110	Needs recycling
Mechanical Pumped-Hydro	--	75-80	Available	400	High capacity, low cost /unit
Mechanical CAES	--	75-80	Available	400	High capacity, low cost /unit
Mechanical FES	65	90-95	Available	350	High power capacity
Chemical Fuel cell	--	25-75	Now developed	18.000	High power capacity
Chemical Hydrogen	--	85-90	Now developed	300	High power capacity

Source: www.energia.gr, SEEI: The Role of Energy Storage in Advancing Large Scale RES Penetration" Conference 2021, Greece.

Doing benchmarking process and based on global literature we consider2 types of ESS having clear technoeconomic advantages, the Pumped-Hydroelectric Systems (PHESS), and H2-Electrolysis Process (H2EL), batteries follow the 2 previous**. PHESS:** is the store up water in dams that reused as power producer after its pumping in times where there is excess power and so on. **H2EL**: is the H2 production through electrolysis and used it, either as air-fuel itself, or in mix with NG in various portions for power production by the existed NG production plants. This utilizes as a primary source the waterfall of the quantities of water collected through pumping in the reservoirs of certain places. Its advantages are, the high capacity, the low OPEX/MWh produced, the small needs for technical changes of NG/CCGG units and its ability to be combined with offshore wind parks that should be located in Thracian Sea, having great wind carrying capacity and using their power for electrolysis. It is noted that the directly exploitable is estimated to 1,2 GW and in more long-term about 9 GW [IEA, IENE, RAE].

Table 88. Technoeconomic characteristics of PHESS Nestos /REMTH.

Characteristics	**Quantity**
Dam's high M	172
Water reservoir M3	110.000.000
Water catchment area KM2	3.698
Water catchment capacity in M3	565.000.000
Waterfall high M	400
Power of plant MW	486
Power production in GWh	430-450
Pumped power MW	380
Today power storage capacity in GWh	320-360
Potentiality for extension MW	120
Additional power storage capacity in GWh	100-140
Cost estimated till 2050 in €	430.000.000

Source: Public Power Corporation-PPC or DEH.

Duration: 24 months and cost: € 430.000.000.

Step 7: Promoting a plan for the best locations of new RES installation-micro-sitting: The criteria proposed for selecting the optimal RES installation site are the following:

- Availability of high wind and solar potential-real carrying capacity.
- Compliance with the special spatial framework for RES, Natura, and Archaeological Protected Areas.
- No optic, acoustic or aesthetic nuisance.
- Ensuring a suitable plot size for the installation of RES and resolving land ownership issues.
- Ability to easy access the area, or construction of the required infrastructure projects.
- The area should be as close as possible to an existing electricity transmission network.

Land planning for choosing the best places can be made by CRES energy maps.

Table 89. Selecting the best installation area for 3 types of RES.

Parameters criteria	**Describing of parameters and criteria micro-sitting**
Wind turbines W/T	• The average wind speed per time period (10 min) or less depending on the accuracy required • The prevailing wind direction in this period. • The maximum value of speed in the period (Gust). • The address of the maximum speed. • The standard deviation of speed (Standard Deviation). • The standard address deviation (optional) • External costs
Solar or Photovoltaic systems P/V	• The climate conditions • The ground morphology, relief, natural obstacles • The total power of P/V park • The collectors types, power, voltage, power intensity and panels' dimensions • The inventors types, power/ voltage input/output • The power transmission networks • The existence of necessary infrastructure • External costs
Hydroelectric plants H/P	• The climate conditions • The ground morphology, relief, natural obstacles • The water quantity that can be stored in dams in stable basis per • The height of water fall • The existence of necessary infrastructure • Maximize installed power • Maximize energy produced • Minimize production costs • Rated flow of each turbine (M3/s) • Net waterfall height (m) • Power of each turbine (MW) • Number of turbines • Installed electrical power (MW) • Expected annual energy production (MWh) • Utilization rate (%) • Water potential utilization rate (%) • Production cost (€ / MWh) • Internal degree of IRR performance (%)

Parameters criteria	Describing of parameters and criteria micro-sitting
	• External costs

Source: Eamonn L. (2010), Integration of variable generation: Capacity value and evaluation of flexibility

Since the land planning of RES influences strongly their efficiency and environmental impacts, it is given more information regarding this very serious issue[84a], [84b].

- **Wind parks**: The wind speed is crucial from many aspects and therefore is the key-criterion for W/T micro-sitting. Further, the levels of sizing and micro-sitting have to be taken in account more 2 key-criteria, the blowing hours/daily and annual average wind-speed, both in timeseries form. CRES has applied original stochastic methods for simulating wind speed in hourly scale and selecting suitable wind turbines. The models for micro-sitting based on statistical analysis of the wind speed variable and the long-term repetition that characterizes it. By any chance, ignorance of such overtime data which can lead to unrealistic forecasts and excessive wind-loading, will have significant effects on energy production and management. Analyzing the time-series of the wind from **NOAA stations** throughout Greece/REMTH, the existence of **Hurst-Kolmogorov** behavior is highlighted, with the method of the escalator. The next step is to be derived synthetic time-series repetition and cyclo-stationarity, for estimating wind loads and expected energy production. (https://www.weather.gov/phi/nwrfaq).

Table 90. Scenario exploitation of wind real carrying capacity of REMTH.

Features of wind potential	>6	>7	>8	>9	>10
Extension KM2: 55,6 KM2	29,8	17,5	6,7	1,2	0,4
Mean speed	6,8	7,8	8,7	10,5	11,9
MW (1860)	1.003,5	698,0	125,2	20,1	13,2
Capacity factor %	24,6	32,1	38,8	47,2	52,3
GWh (2.546,6)	1304,6	991,2	194,0	33	23,8

Source: CRES reports 2010-2020 -adaptation, and compilation by author.

- **Photovoltaic Parks**: For the selection of a techno-economically more advantageous location foe P/V systems, we must take in account the value of the total annual solar radiation. At the level of sizing and micro-sitting we select the daily/annual of solar radiation as timeseries in order P/V parks to be exploited at the most performance.

Table 91. Features of Photovoltaic and solar systems of REMTH.

Features of P/V potential	>600 KW/m2	>900 KW/m2	>1200 KW/m2	>1500 KW/m2	>2000 KW/m2
Extension KM2 : 2450 KM2	29,8	17,5	6,7	1,2	0,4
Mean solar radiation	1.450	1.450	1.450	1.450	1.450
MW (1800)	1.003,5	698,0	125,2	20,1	13,2
Capacity factor %	24,6	32,1	38,8	47,2	52,3
GWh (2.546,6)	1304,6	991,2	194,0	33	23,8

Source: CRES energy maps 2001

The next table shows the pros and cons of P/V parks.

Table 92. Features of water potential for power production.

Pros	Cons
• No noise pollution	• Esthetic and physical footprint
• No air pollutant emissions	• They need storage systems for excess electricity
• Low life cycle GHG emissions	• They need hydro-power systems as reserve units to balance supply/demand
• Low maintenance /spares cost	• Sometimes they use land with great opportunity cost
• Great lifetime operation	• Stochastic power production

Source: CRES reports- adaptation, and compilation by author.

Step 8: Promoting smart macro-networks and micro-grids and smart electrometers. REMTH's ES has begun to integrate several smart digital technologies and new electromechanical systems into the following activities:

1. Electricity generation, and wholesale/retailing management
2. Electricity transmission,
3. Electricity distribution and
4. Electricity supply.

Its power grid should become smarter, more reliable, and efficient, with less environmental impacts by leveraging digital technologies in conjunction with the great share of on/offshore RES. In the digital era, REMTH it is possible to switch to a faster, smarter electricity grid, which will:

1. Provide better quality electricity with 2-way communication,
2. Balance power supply/demand in real time, smoothing out the peaks demand
3. Make consumers active participants in the production/consumption of electricity.

Yet, the general guidelines of NPEC 2021-2050 can help EU regions and REMTH to pass faster from today traditional technology networks/grids to new smart having the ability to manage power supply/demand through functions like storage. Such innovative interventions will need investments about € 210-220 million, but their technoeconomic and social/environmental contribution is estimated more than € 916 million till 2050, eg €706 million net profit in NPVs. [8], [112].

Table 93. Describing REMTH's grid upgrading actions for a cost-effective energy transition.

REMTH's grid upgrading actions and technologies	Describing REMTH's grid upgrading actions for a cost-effective energy transition	Cost estimated
Grid supervision, control, and management-€ mil		**22,0**
	• Automatic Voltage Regulation-AVR application • Precise Grid Load Forecast • Automatic energy quality evaluation and calculation	
SCADA and DMS operation		**5,0**
	• Improving the quality of the supplied electricity, the reliability of the DPA Network • Advanced network management capabilities, resulting in reduced facility load during periods of increased demand, reduced power, and grid power losses • More efficient human resource management during failures and better handling of multiple Network events • Homogenization of remote control and systems digitization of all network data • System scalability with the ability to add a large number of remote controls • Remote control of network components and telemetry of network data	
Apps of Digital Management System		**5.0**
	• Load flow analysis, Outage report, and Switching orders • Distribution Feeder Optimization, Short Circuit Calculator- Protection Coordination • Optimization of System Average Interruption Duration Index-SAIDI	
Installation of a smart GIS		**10,0**
	• Mapping of Distribution network maps in digital form, replacement of the today handwriting system by a GIS, facilitate the collection, updating, handling and processing of the vast volume of geographical and descriptive data • Keeping in database form information about the equipment and the status of the REMT's grid supporting of the daily activities of the Distribution • Improving the quality and speed of Administrative Information at all levels and effective decision support based on the processing of up-to-date and reliable data • Better maintenance planning for least outages	
Smart planning for extending and upgrading REMTH's grid		**8,0**
	• New Customer Service Information System and Call Centers • Supply chain and MIS reorganization	
Smart power meters		**165,0**
	• Reduction of energy consumption by shifting power peak /end user	

	• Reduction of metering and outage costs for the Network Administrator • Better estimate of demand forecasting and accurate clearing of the wholesale market	
Total cost in million €		**215,0**

Source: Macrogrids or microgrids: which Is The key to the renewable energy revolution? www.cleantechnica.com/ adaptation and compilation by author.

Duration: 10 years and cost: € 215.000.000.

Step 9: Promoting Energy Storage Systems-EES- for better handle of variability through greater flexibility of REMTH's ES. To transform REMTH's ES dominated by RES with a share of greater to 60% it is needed greater flexibility and storage capacity aiming to harnessed completely the ES. Power production by RES should be managed by 80% via storage systems and by 20% via smart flexibility-NG units. If the necessary investments in networks carried out till 2045, then REMTH should become a regional power hub in S.E Europe. Yet, the investments in ESS in REMTH, will boost the entire Greece's geopolitical and economic role in Europe. ESS are divided into 3 types **a**. storage systems connected with specific hybrid projects **b**. storage systems exclusively store and trade energy in the markets, **c**. storage systems that exclusively smooth the load curves and trading. The positive effects of ESS contribute to, decreased variability of ES, optimal balance of supply/demand, greater stability of ES, better ancillary stock, and best regulatory control [67a]. The issue of storage is inherently related to RES, as their stochastic production is not sufficient to balance supply/demand in dt time. According to literature every 10% of new power from RES causes need for new storage capacity equals to 6,5% to new RES power. When ESSs are equal to 65% of real capacity in MW of RES in the power mix (P/V 40%, W/T 47%, rest RES 13%, then the ESSs are capable to stabilize and balance P/V 40%, W/T 47%, rest RES 13% the REMTH's network by 96,2%. [67a]. Yet, the new digitalizing production/supplying/storage systems can stabilize the investment cycle of the units, since as "the more share of PV/WT to REMTH's power mix, the more PV/WT curves of load will match". The ESSs in REMTH will have 5 forms as they are given to table below [20], [25], [27], [38], [55], [112], [113].

Table 94. Energy storage systems and the potentiality to be carried out to REMTH between 2021-2045.

Electric 1%	**Electrochemical 5%**	**Chemical 70%**	**Thermal 3%**	**Mechanical 20%**
ES based on condensers	Batteries lithium	Green H2 storage	Sensible TES	Hydro-Pumped
Superconducting magnetic ES	Batteries NaS	Synthetic NG	Latent Heat ES	Compresses air ES
	Batteries PbO2	Fuel cell technique	Thermochemical E.S	Flywheels_ES
	Batteries NiCd			
	Batteries Flow technique			

Source: Denholm et al. (2011) "Grid flexibility and storage required to achieve very high penetration of variable renewable electricity", Energy Policy 39, pp 1817 – 1830".

Each of the energy storage technologies has some unique features that make it suitable for a specific application of REMTH. These unique features helped us to suggest the best technology for the REMTH, via a benchmarking system-see analyses and tables below.

Table 95. Evaluation of above Energy Storage Systems based on technical, economic, and environmental characteristics.

ES technology	**Density of ES MWh/ton**	**Regaining efficiency %**	**Availability and technology maturity**	**Capital cost €/KW**	**Advantages**
Electric ES Electric SMES	300	85-98	Immature	600	High performance, great lifetime
Electrochemical NiCd	70	65-95	Available	500	High power and performance
Electrochemical Li	115	95-100	Available	200	High power and performance
Electrochemical PbCd	35	75-80	Available	110	Needs recycling
Mechanical Pumped-Hydro	--	75-80	Available	400	High capacity, low cost /unit
Mechanical CAES	--	75-80	Available	400	High capacity, low cost /unit
Mechanical FES	65	90-95	Available	350	High power capacity
Chemical Fuel cell	--	25-75	Now developed	18.000	High power capacity
Chemical Hydrogen H2	--	85-90	Now developed	300	High power capacity

Source: www.energia.gr, SEEI: The Role of Energy Storage in Advancing Large Scale RES Penetration" Conference 2021, Greece.

Table 96. Technoeconomic characteristics of PHESS Nestos /REMTH.

Characteristics	Quantity
Dam's high M	172
Water reservoir M3	11.000.000
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Water catchment capacity in M3	565.000.000
Waterfall high M	400
Power of plant MW	486
Power production in GWh	430-450
Pumped power MW	380
Today power storage capacity in GWh	320-360
Potentiality for extension MW	120
Additional power storage capacity in GWh	100-140

Source: Public Power of Electricity-PPE.

Additional information for H2EP**:** H2 production technologies are the only storage technologies that have the ability to channel stored power to other end-use sectors, transportation, buildings, heat generation in industry, chemical production, and electricity generation. In REMTH till 2050, the NPEC and other experts estimate that H2's share in energy mix will increase from the current 0,1% to about 20% in 2050. It is predicted that by 2050, the next quantities of H2 will be stored:

- Greece: 24 TWh from total 73 TWh of total power demand
- REMTH: 1,8 TWh from total 3,3TWh of total regional power demand.

These mean that the share of H2/store system will cover in country/REMTH 70% - 78% of the total stored energy, while the power of electrolysis systems for H2 [110], [Rachid El Mrabet et al. 2021, "Hydrogen production and derivatives from renewable energy systems for a best valorization of sustainable resources" in Hybrid Energy System Models]. Duration: 20 years and cost: € 330.000.000.

Step 10: Promoting offshore RES, W/T and P/V systems in Thracian Sea. European Commission did an adhoc plan about offshore RES to help its members to meet the EU's goal of climate neutrality by 2050. The plan proposes:

1. Increase Europe's offshore wind capacity from current level of 12 GW to, at least, 60 GW by 2030 and to 300 GW by 2050.
2. Increase Europe's offshore solar capacity from current level of 0,4 GW to, at least 25 GW by 2030 and to 70 GW by 2050.

For this reason, will have to be used advance technologies -floating wind and solar high-performance systems by 2050. Further, this ambitious growth will be based on the vast potential across all of Europe's seas and on the global leadership position of EU firms in the energy sector. This strategy will create new opportunities for industry, generate green jobs across the EU, and strengthen the EU's global leadership in offshore energy technologies. It will also ensure the protection of EU environment, biodiversity, and fisheries. It is noted that in Greece and REMTH the offshore P/V parks are not promoted due to more radiation /M2 within seas but due to lack of suitable land.

Despite the rich wind/solar potential, Greece /REMTH have not yet developed offshore wind and solar parks-SWP. Greece and REMTH will have to install respectively about 5,7/1,5 GW till 2040 and 8,0/2,3 GW till 2050 producing the 60% of electricity demand, the rest from onshore systems. The technology of fixed bearing at the bottom of shallow sea for SWP do not match to Greek/Thracian seas, being very deep [32], [105], [106], [117], [118]. Since SWP systems can be installed in Thracian Sea places with greater depths, mean depth 46,8 m, expanding the usable sea wind potential and this will allow the mass installation of very large wind farms, more than 100 MW. The law 4546/2018 copes with offshore RES and facilitates their development. According to results of a study, the total capacity of the offshore wind potential that could be exploited through floating SWP in Thracian Sea ranges from 1.700 -3.600 MW (Institutional framework for marine wind farms: international experience and basic design principles for Greece/ Draft of Ministry of National Economy 2021- Offshore Wind Worldwide Regulatory Framework in Selected Countries, Hogan Lovells, World Forum Offshore Wind, 2020). In summary, the optimal exploitation of wind maritime capacity, is given to the next table.

Table 97. Two indicative scenarios for sea-plan of wind turbines.

Thracian sea area	Moderate scenario-Number of turbines	Moderate scenario-power of turbines MW	Optimistic scenario-Number of turbines	Optimistic scenario power of turbines MW
Alexandroupolis	78	546	136	952
Samothrace island	31	217	55	385
Fanari	59	413	110	770
Thasos island	38	266	66	462
Total	206	1.442	347	2.569

Source: National Project for Development of SWP-NPDSWP -CRES 2013 Draft 2021.

An interesting issue is the method to select the best sea area for installation offshore RES. There are 2 methods of SWP, the centralized and decentralized. (Laws: 3468/2006, 3851/2010, 4416/2014 and 4546/2018).

- **Centralized:** the state selects the zones, areas, and time of implementation of SWP's, based on its long-run planning for RES and the Marine Spatial Planning. A competition is held for the positions pre-selected and evaluated by the state through some criteria. The bidding process is based on the principle that the concession is awarded to the successful candidate together with the required permits, for a maximum period of 30 years, including the construction and operation phase.

- **Decentralized:** the state regulates SWP development through maritime spatial plans and environmental laws. It selects the investors who will have the right of preference in the development of SWP in wide sea zones, through a tender process. The licensee assumes full responsibility for the design, technical studies, precise location of the wind turbines and the licensing of both, the SWP installation and the connection with the existed or new grid. Also, the bidder is responsible for consultation with the local communities in order his project to be accepted without any protest. In conclusion, in the end of transition of REMTH in 2050: RES capacity= 3.850 MW, ESSs capacity=3.850X 0,65= 2.500 MW. Duration: 20 years and cost: € 330.000.000. To the next figure 29 is a chart presenting the sea-areas suitable for SWP

Fig. 29. Sea-areas suitable for SWP-Source: CRES 2016.

Conclusions about the 10 steps:

The main strategic goals of this proposed roadmap until 2050 are the following:

- Further development of electricity generation by 67,8% using onshore/offshore RES.
- Upgrading and strengthening of infrastructure in the total energy sector and networks to facilitate RES and gradual coupling of final energy consumption sectors.
- Improvement of energy saving efficiency everywhere since, the energy saved is the cheapest and greenest because it was never produced and used.

Just transition from NG to RES almost by 90-95% in power mix till 2050.

8.9. Sectoral analysis of transitions' impacts in REMTH'S ES: cost and competitiveness

The energy sector-production, supplying, transmission and distribution, contributes to REMTH's GDP 6,5%, employs directly/indirectly/induced way 1.845 people and yields a gross added value of €250 million corresponding to 5,3% of total added value of the non-financial business economy. There are two macroeconomic models used in the study of transition's impact on a regional economy like REMTH's

and more comprehensive insights than what each of them could provide separately. The factors used as variable by models include the following:

- **Transport:** means reducing travel demand, shifting to public transport, improving the efficiency of various transport modes, shifting to electrified mobility. Buildings: means increasing compactness of new buildings, improving their insulation, improving efficiency of their heating /cooling systems-heat pumps. Industry: means improving the efficiency of industrial processes, shifting to higher energy use performance and lower GHG emissions.
- **Energy supply:** means shifting to RES, increasing use of biomass, beyond P/V-W/T.
- **Energy taxation:** is considered the most effective economic tool aimed at reducing GHG emissions by all economic activities, as it can address energy management issues by equating the private cost of CO2 emissions with the social benefits caused by less pollution. Energy taxes provide incentives to use clear energy and energy saving technologies. Greece/REMTH should adopt an integrated and symmetrical environmental tax policy-CO2 tax, supporting climate protection in the sense of the pollution cost to be paid fairly. Revenues from CO2 taxes could preferably be used to fund greater RES penetration and CO2 reduction systems. The issue of competitiveness in tackling environmental problems is particularly important for both, economic and environmental reasons for REMTH. If environmental policies negatively affect competitiveness, it will lead to sectoral and national economic decline. The risk of carbon leakage is wider, as it also concerns sectors that are obligatorily involved in the GHG emissions trading system of EU-power production. The lack of protection of these industries through the free allocation of GHG allowances can have additional negative economic consequences. The quantification of the effects on the REMT's economy by passing the additional cost of CO2 trading rights at electricity prices, will cause an indirect cost to its economy estimated to -15-25%(NPEC 2021). The increase in electricity costs has an adverse effect on the competitive position of industries of REMTH, especially those are energy-intensive in their production process. Recognizing this cost risk, EU issued the Directive 2009/29/EC, proposing relief measures for certain firms, such as financial support to offset increases in electricity prices, resulting from the CO2 trade costs. The measures are voluntary, and their implementation is at the discretion of each Member State. The 5 REMTH's industries with greater pollution are, NG/CCG(1), textile (4), food(17), chemical (5) and aluminum profiles (3). They have been identified as exposed to the risk of carbon leakage due to the indirect cost of GHG emissions that have important directly contribution to REMTH's economy: 8,8% to R-GDP, 8,6% to Gross Added Value and 9,2% to employment. Taking into account, the multiplier effect resulting from the interconnections among the sectors of economy as an indirect effect, the wider impact of the income arising from the direct, indirect and induced activities is estimated, in R-GDP to € 278 mil, in GAV to € 102 million and in employment 1.945 jobs. Each new energy GAD unit adds 5 new GAD units in the whole regional economy and each new full-time job in the energy produces 6 new jobs to other sectors. For the further estimation of impacts of transition to REMTH's economy, we used the Multiple Regression Model-MRM and the scenario of 80 €/CO2 ton. The MRM helped us to determine the correlation between dependent and independent variables. We found out that, the higher the price of CO2 trade, the greater increase of electricity costs. These costs are passed on to final power prices, burdening end-users and lead to less firms 'cost competitiveness. The table below shows how CO2 taxes impact on economic structure of 5 industries in REMTH, using the MRM [14], [31], [39], [59]. The 5 industries

were the independent variables and the 5 firms characteristics independent variables.

Table 98. Estimation of CO2 trade system and its impact in 5 industries.

Sectors/industries	Portion of power cost in total cost %	Added value %	Employment in LPAE*	Export share of total exports %**	Financial health (Z) according to Z-score
Power production	22	39	448	5,3	2,92
Textile	61	50	985	32,1	2,11
Food	31	58	314	4,6	2,91
Chemical /plastic/pharmaceuticals	37	105	876	39,4	3,34
Aluminum/profiles	57	371	1.123	18,6	3,23

*Levelized Permanent Annual Employment

** Exports only manufactured products

*** To determine the financial health of firms under study, we used a variant of the Z-score calculation formula, originally developed by Altman Edward [17], to determine the probability of bankruptcy of listed companies. The Z-score is an empirical measure calculated from the balance sheets and income statements of companies. The Z-Score general model has the formula: $Z = 1.2 X1 + 1.4 X2 + 3.3 X3 + 0.6 X4 + 1.0 X$. Depending on the resulting Z-score, a firm is classified as safe, in the "gray" or in the extremely dangerous zone, in terms of the probability of bankruptcy.

To calculate the Z-score we used 5 years balance statements published 2013-2017 and the following formula:

Z '= 0. 698X1 + 0.864X2 + 3.200 X3 + 0.390X4 + 0.985X5…

where,

X1 = Current Assets / Assets are released

X2 = Reserves and results in new / Assets

X3 = Net result / Assets

X4 = Equity / Liabilities

X5 = Sales / Assets

If Z'> 2.85, the firm is classified in the safe zone

If 1.25 <Z<2.85 the firm is classified in the gray zone

If Z '<1.23 the firm is classified in the distress zone

The impacts of CO2 emission tax in Greek/REMTH's firms and economy are given to the next table.

Table 99. Impact of CO2 emission cost in Greek and REMTH's economy.

Economic data-for 50€/ton CO2-conservative scenario	Greece	REMTH	Differences in levelized basis €/capita
Gross production in million €	1.090	44	104/72=1,44
Changes in added value in million €	-470	-19	45/31=1,45
GDP changes in million €	-500	-20	48/33=1,45
Incomes of work productive factor in million €	-146	-6	14/10=1,40
Taxes and social security contribution in million €	-75	-3	7/5=1,40
CO2 trade indirect cost in million €	-78	-3	7/5=1,40
Net exports in million €	-87	-4	7,5/5,2=1,44
Employment in million €	-9.607	-480	915/789=1,20

Source: EIRE 2018, elaboration, adaptation, and compilation by author.

Since the CO2 tax tends to be increased-IENE estimates it to € 100/ton, mainly now where the COVID-19 crisis is ended, we consider useful to give the % contribution of total quantified impacts in order the energy policymakers to be aware about them.

Table 100. Distribution of CO2 trade in direct, indirect, and caused as % - CO2 tax 50€/ton in Greece/REMTH.

Economic factor and the impacts	Direct %	Indirect %	Induced %
Gross production	32,1	28,0	39,9
Changes in added value	17,9	27,4	54,7
GDP changes	19,0	28,0	53,0
Incomes of work productive factor in million €	24,1	31,0	25,9
Taxes and social security contribution	26,7	33,3	40,0
Employment	15,2	30,5	54,3

Source: EIRE 2018, elaboration, adaptation and compilation by author-the contribution estimate through MRM considering one variable changeable and the rest stable.

The figure below shows how the values of CO2 tax impact on growth rate- two values €50/ton and € 100/ton have entirely opposite relations.

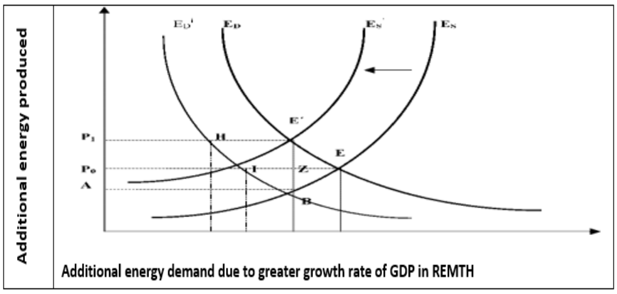

Fig. 30. Impacts of two different values of CO2 tax on growth rate.

The next table shows the impacts of whole ETS in REMTH's economy.

Table 101. Impacts of ETS in Greece and inductively in REMTH's economy.

Macroeconomic impacts	**Description of impacts**	**Estimation by %**
In growth rates of GDP	Since positive impacts are greater than negative the final impact will be positive	0,3
In competitiveness of total economy	In initial phase it will be decreased and to mid-macro term basis it will be increased	-1,0 to 5,0
In increase of domestic added value	In mid-macro term basis it will be increased because RES systems are high tech energy equipment	22,0
In increase of employment	Initially during the construction period it will be increased, after that will decreased but in mid-macro term basis it will be increased slowly but with stable rate.	-10,0 to 15,0
In electricity price	ETS impact was small because Greece carried out a smart system of emission rights	1,0-2,0
In income distribution-Gini Index	Even if energy taxes are a cost-effective tool, its cost-sharing is an important factor in determining its acceptance. The results of various surveys on the effects of energy taxation on income distribution are ambiguous, so we consider them neutral	0,0
In GHG reduction	ETS has strong positive impact on GHG reduction comparing to 2005	25,0

Source: EU/EC 2018 "Consolidated version of Directive 2003/87/EC of the European Parliament and of the Council establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC".

8.10. The risks owed to transition's large-scale projects

Risks in relation to investments in large-scale RES projects can be described by negative impacts due to RES uncertainties about the high-power production variability caused by extreme events. In our case, transition risks refer to ability of REMTH's authorities to manage a such mega-project in a satisfactory way, despite the risks implied extreme events occurring by any chance. Three categories of risks seem to play the most dominant role.

- **Technological risks:** owing to malfunctioning of the technology used and potentially can be large for some RES technologies.
- **Operational risks:** are related to increasing costs for maintenance, spare parts and protection.
- **Regulatory risks:** can be caused by unpredictable changes in the financial support for RES due to changing of state policies.

The sense of risk in energy is linked with the concept of high uncertainty, with the view that there is no way to know if the expected outcomes will be profits or a loss. Uncertainty is the most common in transition, arising from scientific findings that are incomplete, or conflicting, so that it can be imposed to support divergent political positions (Sarewitz D, 2010. World view: Curing climate backlash. Nature News 464, 28– 28). In order to quantify the transition risks we use an ad-hoc VaR-Value at Risk model with 5 pseudo-variables we formulated the bound average risk value and model the variability of the REMTH's ES-see below. As with many other financial models, the formula for calculating the risks is either:

$$VaR = vm\,(vi\,/\,v(i-1))$$

where M is the number of years from which historical data is taken, v_i is the 5 variables Xi1… Xi5 on year i,or :

$$VaRt = \lambda\sqrt{SDV}tp$$

where λ is the likelihood parameter, SDVtp is the return standard deviation for time t and y is a parameter used when we calculate VaR for a time period with a length different from that used to estimate the SDV.

The purpose of the formulas is to calculate the percent change of each risk factor for the past 30 trading years. Each percent % change is applied to current market values to determine the cost of the 3 types of risks. Ad-hoc tests gave the values:

Table 102. ADF test statistics and critical values for the original series.

Critical value %	**1**	**5**	**10**
Value	-3,4634	-2,8610	-2,5811
ADF Test - statistics	------------	-7,577756	------------
Variables	Coefficient	Standard-Error	t-Statistic
C	0,29543	0,140522	2,110624
AR(1)	0,222398	0,056156	3,959861
Number of lags in 3 periods	2030	2040	2050
Probability	0,873	0,542	0,397
Q-Stat	32,764	25,256	15,267

The next table outlines the risks owing to great power variability supply for selected power mixes with great share of RES that needed large investments.

Table 103. Risk factor for REMTH's ES due to variability /stochasticity of RES power production.

Risk Factors due to variability of ES	**Describing**
Risks owing to power production and average costs cost	• Assess current levels of curtailment and loss of load • Assess overgeneration incidents and fluctuation of prices • Assess cycling of units (start-up ramping and min gen incidents) • Assess if operating reserves are adequate
Risks owing to network/grid systems	• Assess if system can efficiently regulate frequency and voltages • Assess if system can recover from unexpected events • Assess if system has sufficient inertia • Assess if transmission elements get overloaded
Risks owing to unlocked existing flexibility	• Regulatory, market changes • Dispatch units based on merit order • Train staff at generating units on operate plants flexibly • Pooling with neighbors • Adjust operating reserves based on new needs
Risks owing to bad implementation of DSM schemes	• Better managerial tools
Risks owing to invest in new not well-planned assets	• Transmission enhancements • Retrofit existing units • Invest on new generation and/ or storage
Risks owing to great cost of optimizing variability using geospatial optimization tools	• Optimize VRE capacity mix • Estimate VRE production based on location and policy goals • Estimate future net-load
Risks owing to Least-cost capacity expansion to identify future assets	• Study the net-load to assess needs for cycling • Optimize non-VRE capacity mix based on future technologies • Identify additional flexibility assets (e. g storage, DSM) • Assess benefits of sector coupling

Source: IPCC Special Report, Global Warming, 2018 and Power system flexibility for the energy transition part 1: overview for policy makers, IENA 2018.

The above table shows that increasing share of RES in REMTH's ES creates complex challenges. From technical/technological view, a successful cope with risks implies, huge investments in smart full digitized ES, faster electrification to transport, upgrading energy saving systems in buildings and construction of smart storage systems-all that include risks that will have to be taken in account for more precise estimation of directly/indirectly transition cost.

8.11. The key-benefits from optimization of power mix

8.11.1 Estimating maximized benefits using SCBA tool

In 2020-2022 the covid-19 pandemic and bad developments in energy strongly affect the REMTH'S economy. Despite the bad conjuncture, projects for reducing the GHG emissions and cost of power generation via high share of RES were continued. The inability of REMTH's existed network/grid to support a larger share of RES is an inhibiting factor. Yet, the lack of organized spatial planning and integrated long-term energy planning consist of drawbacks and do not support a clear background for attracting energy investments in RES sector. Local societies today realize the importance of transition for the growth rates of their region. Also, the impact of power production technologies for a cost-effective transition depends on several techno-economic parameters [4], [5], [10], [14], [22], [31]. The next table gives the basic factors influencing the energy transition and being well realized by local societies.

Table 104. The basic factors influence energy transition in REMTH influencing societies 'views.

Categories of impacts	**Factors**	**Description and comments**
Environmental	• Water reserves • Air quality Impact on biodiversity • Optic disturbance • Acoustic nuisance • GHG emissions	Conventional power generation technologies had 304% more negative impacts on environment of region than RES ones. It is hoped till 2050 the natural and anthropogenic environment will be far clearer than today
Economical	• GDP • Income • Consumption • Electricity prices • Commercial balance • Investments in energy	Consumption and Income are also affected both nationally and mainly locally when the energy infrastructure occupy a significant part of the local population.
Employment	• Higher productivity • More employment	The energy sector is the first in productivity per employee in the EU and REMTH. As new technologies and automations enter in

	• Upgrading workforces' skills	the industry there is a need for labors with high skills so that they can respond to new technologies. According to a relevant study, 600 permanent and 1,000 part-time jobs medium to highly skilled can be created by 2035 in the new energy technologies.
Residential	• Land use • Changes in land value	Usually the existence energy facilities is excluded for residential use for at least some distance from the facility for both reasons, safety, and nuisance
Population	• Change of population characteristics	This effect affects REMTH if it is needed labors to be come from other regions for high expertise
Technological	• Energy mix	As new technologies will be added to REMTH's energy mix with different characteristics (RES, Natural gas), forming relevant technological challenges concerning energy mix production, ES stability, peak demand, etc.
Educational	• New training programs	New technologies create a demand for well qualified workforce, so the educational institutions have to adapt their training programs to enable to meet market demands.
New strategies	• The role of REMTH in the energy map of SE Mediterranean	REMTH is called to play the role of energy hub through the implementation of major energy infrastructure projects that will connect Europe with Asia

Source: RAE report 2020, NPEC revised report 2021.

More useful is the next table where the part of above benefits are given in quantified form, influencing more societies, and used for quantification of benefits through SCBA tool.

Table 105. Necessary data for SCBA analysis.

RES technology/ criteria	**CO2 emissions**	**P/V onshore**	**P/V onshore**	**Onshore W/P**	**Offshore W/P**
Liifetime operation in years		25	25	25	25
CO2 emissions as indirect variable ETS cost					
Natural Gas Kgr/MWh	272-1000	---------	---------	---------	---------
Wind turbines Kgr/MWh	9-18	---------	---------	---------	---------
Photovoltaic Kgr/MWh	31-90	---------	---------	---------	---------
Hydro-power systems Kgr/MWh	45-226		---------	---------	---------
Geothermal Kgr/MWh	45-90	---------	---------	---------	---------
Financial scheme and costs					
Share of debt %		80	82	80	70
Share of equity %		20	18	20	30
Interest rate on debt %		3,5	4,0	4,0	5,0
Return on equity %		6,5	7,0	7,0	10,0
WAAC nominal %		4,1	4,6	4,6	6,0
WAAC real %		2,1	2,2	2,5	4,8
OPEX fix €/KW as 2,5 % of CAPEX		0,0	25,0	30,0	100,0
OPEX variable €/KW		0,0	0,005	0,005	0,005
Degradation %		0,0025	0,0025	0,0	0,0
CAPEX €/KWh low		850	1.200	1.500	3.200
CAPEX €/KWh high		1.100	2.320	2.000	4.800

Source: RAE report 2020, NPEC revised report 2021.

Conclusion from above:

- Although, there are 2 alternative techno-economic methods to a SCBA of achieving maximum benefits, the Linear Programming (LM) and the Multicriteria Decision Making (MDM). We chose the SCBA and LM ones since they are more understandable by the majority of energy stakeholders and then we compare the results.
- Local societies support transition activities and projects considered them as necessary and additive to those proposed by regional authorities.
- Beyond the public sector, the private one can play an equal active role in upgrading natural capital so that together with societies to succeed in the best outcomes.
- It has to be determined REMTH's crucial ecosystems providing the greatest benefits.
- It is needed ad-hoc actions for power supply network by thickening it so that to be more resilient to extreme events.
- Representatives of local societies have to participate to transition large projects evaluation through SCBA, ensuring better balance between positive/negative externalities, and make a well-balanced natural capital bud.
- Maximizing of transition benefits means optimizing power mix outcomes- technologically and operationally- therefore the best share of P/V and W/T. The other RES contribute less than 10% and so that they have little impact.

- **Implementing SCBA method**:SCBA is the most simple and understandable method to evaluate large and complex projects like energy transition. The method is based on standard economic data calculating in current, or standard monetary values all the factors and parameters tanking place in the system under study. In practice, from the technoeconomic data of the previous tables, can be derived the next table which presents in benchmarking basis the 2 basic types of RES, P/V and W/T based on absolutely adhoc weighted technoeconomic criteria. The criteria take into account different factors that are evaluated through their gravity and result to final outcomes. The gravity indexes came from global literature, and they simply were adapted and compiled to REMTH's energy structure and conditions.

Table 106. Comparison and benchmarking between P/W and W/P using adhoc technoeconomic criteria.

RES technology/outcomes -25 years	100% P/V	100% W/T	Gravity benchmarking index-P/V	Gravity benchmarking index-W/T
Total power in MW–X1	1.800	1.860	5	5
Energy generated in MWh—X2	2.430.000	2.976.000	6	8
Revenue from energy in current mill €--X3	8.075.000	10.450.000	6	8
Costs				
CAPEX+ storage systems for each case in mill €--X4	2.916.000	3.869.000	8	7
Loan for funding CAPEX 70%-mill €--X5	2.041	2.708	5	4
OPEX for each case in mill €-X6	911.000	1.488.000	7	6
Financial cost in million €-loan 70% 0f CAPEX-X7	3.025.000	3.525.000	6	5
LCOE-Levelized Cost Of Energy €/MWh-X8	45,4	45,6	5	5
System Marginal Cost €/MWh-X9	4,5	4,8	5	5
Contribution to electricity generation for each RES technology in the year 2020 in %-X10	8,8	11,2	5	5
CO2 reduction %-X5	90	90	5	4
External environmental cost ¾ €/MWh/year-X11	182.250	297.600	6	5
Total costs-X12	7.034.250	9.179.600	5	4
Benefits before taxes –X13	1.040.750	1.270.400	5	9
IRR- % X14	13,46	14,38	5	9
NPV in mill € -X15	1.165.450	1.486.000	5	9
Break Even Point %-X16	65	61	5	4
New permanent jobs-X17	556	382	6	6
Local added value-X18	45	32	5	4
Necessary for storage systems in MWh-XX1919	486	476	5	6
Total points			110	118
Proportion between 2 RES %			48	52

Source: Climate Action Tracker -CAT 2020 report as Methodology Notes- A social cost benefit analysis of grid-scale electrical energy storage projects: A case study, Sindhu AJ 2017.

The above table gives the final results that prejudge as the best mix that with the proportion P/V=48% and W/T=52%. To this proportion 48/52, the benefits are the greatest and the costs the least.

8.11.2 Estimating maximized benefits using Linear Programming tool-LP

The running/ implementation of SCBA tool resulted to outputs regarding the optimal energy mix that will have to be carried out towards 2050. The LP was used to optimize technoeconomic benefits/costs implicated to transition process. Essentially, LPM defines the Objective Function which has to maximize the benefits and minimize the costs. Transition ,as maximization problem, needs 2 approaches in order to be solved, the Single Objective Optimization-SOO, and the Benefits Objective Maximization-BOM. The variables X1, X2…. X19 that have used in the table below, define the set of values from which the optimal solution can result. The constraints put are technical, technological and economic and they do not influence the final outcomes, the solution has to satisfy them. The generalized formula of optimization problem is mathematically defined as finding a vector:

$$x^{\rightarrow} = [x1, x2, \ldots, xn] \in \vec{S}, where\ \vec{S} = S1 \times S2 \times \ldots \times Sn, Si \subseteq IR, i = 1, \ldots, n$$

which maximizes the functions $\vec{\boldsymbol{f}}(\boldsymbol{x})$.

This definition covers all possible optimization problems, as minimizing -$\mathbf{f}(\mathbf{x})$ is equal to maximizing $\mathbf{f}(\mathbf{x})$. The optimal solution of f(x) is sought throughout the field of acceptable solutions, therefore, it is called Global Optimum-GO. Yet, this optimization method is without restrictions-exempt two technical ones put in advance- so that with the appropriate interventions in the f(x) to be solvable as maximization problem, Further, tests performed with Langrage and Karush-Kuhn-Tucker techniques, KKK-tests shows the reliability and accuracy of method. The objective function results as:

$$NPVtechnA(X_\iota = 1, \nu, \ldots, X_\iota = I, \nu, \ldots, \Theta_\iota = 1, \nu, \ldots, \Theta_\iota = I, \nu) = maxA$$

where X_i are the variables presented to the table below.

Table 107. Variables and parameters take in account to our model.

Symbols of variables Xi	Describing the symbol
Ta =X1	Technology availability factor I as part of time availability %
Taf=X2	Technology availability factor (i) in relation to the total available load
Tic=X3	Coefficient of technological improvement of each technology (i)
Tc=X4	Technology capacity orders (i) in the period (v) before the base year
OPEX=X5	Operating and maintenance costs of technology (i) in year (z) [€ / MW]
Ed=X6	Total electricity demand in MWh
Dr=X7	Discount rate [%]
NRc=X8	$CO2$ technology emissions (i) in equivalent tons $CO2$
TNc=X9	Available technology natural resource capacity (i) in MW
Tce=X10	Rate of contribution to electricity generation for each technology (i) in the year 2020 in %
Ict=X11	Installed capacity for each technology (i) in the year 2050 [MW]
T2=X12	Total number of technologies-in our case -2 cases
Ict=X13	Investment cost of the technology capacity order (i) over time (v) in € / MWh
AICt=X14	Annual investment cost of technology capacity (i), payable during the period (z) in € / MWh
Ict=X15	Installed capacity of technology (i) per year (z) in MWh
CSm=X16	Capacity safety margin for peak hours in %
Uef=X17	Unit efficiency factor (i) in %
NPV=X18	NPV in €
CO2e=X19	Emission allowance price $CO2$ per year (z) in € / tons $CO2$
PE1, PE2=X20	Price of electricity for RES technologies per year (z) in € / MWh
Maxt, Mint	Maximum and minimum annual production level of technology (i) in MW
Mde=X21	Maximum energy demand per year (z) in MW
Te=X22	Total electricity generation per year (z) of technology (i) in MWh
EC=X23	Electricity consumption at time (t) of year (z) in MWh
Rr=X24	Revenue from RES technology (i) per year (z) in €
Tn=X25	Number of technologies based on RES
Iry=X26	Interest rate in year (t) in %
CT=X27	Construction time of the technology station (i) in years
LTt=X28	Lifetime cycle of a technology unit (i) in years
Toh=X29	Total operating hours of one year
Ceres=X30	Degree of capacity exploitation of RES technology

Running the above data via Matlab platform-this application involves using the Command Window as an interactive mathematical executing text files containing MATLAB code. The process of solving our model is: Defining model parameters → Defining parameters of REMTH's ES→ Data mining process → Creating a scenario application roadmap→ Calculating of objective function → Calculating any constraint functions emerged during run program → Checking the termination criterion → presenting results → Criticizing and commenting results. From the solution of the above objective function:

$$NPVtechnA(X_{\iota} = 1, \nu, \ldots, X_{\iota} = I, \nu, \ldots, \Theta_{\iota} = 1, \nu, \ldots, \Theta_{\iota} = I, \nu) = maxA$$

With 20 Xn variables and 10 parametrical variables we result to optimal power mix P/V 46,6% and W/T 53,4%. So the 2 methods result to almost similar results, the differences are less than 5%.

The above energy mix leads to a max current revenue of € 3.365.000.000 that converted in NPV takes the price of €2.651.450.000. By a sensitivity analysis-increasing/decreasing the share of PV/WT should find that, the key factor influencing the optimization of NPV is, first the quantity of electricity production (35,7%) second electricity prices (26,3%), third the capacity factor (17,3%), forth external environmental cost (11,0%) and fifth all the rest, consisting of 9,7% [5], [11], [13], [17], [22], [64].

8.12. Synergies between transition and Environmental Social Governance (ESG)

ESG ratings and investment approaches represent an important tool for integrating sustainability into investment processes, and in concept would serve to support investors in making better decisions about resources allocation. ESG practices would help financial investors who seek to evaluate the financial materiality of non-financial reporting as to the conditions, practices and strategies related to environmental, social and governance risks and issues over the mid to long term. Yet, ESG could support risk management to reduce the impact of climate change and other sustainability risks on corporate performance over time and navigate a shift to RES strategies which would bring new growth opportunities.

ESG performance is accelerating and enabling energy and financial institutions and insurers to evaluate countries, regions, and companies'. ESG performance, pushing investments towards sustainability facilitates the transition to all its aspects. According to ESG policies, transition plans, corporate strategies and investment practices take the form.

Table 108. ESG policies, transition plans, corporate strategies, and investment practices.

Inputs	Outputs	Outcomes
Production inputs	Emissions	Ecological and biodiversity footprint
Energy mix	Waste outputs	Exposure to risk
Power Supply chain inputs	Other pollutants	Environmental impact

Source: Boffo, Marshall and Patalano (2020), ESG Investing: Environmental Pillar Scoring and Reporting, OECD

The right RES technologies are vital to meeting the ESG standards of REMTH. The below REMTH's ESG indices reflect the successful implementation of good changes of its ES, in a period of time, as the ES develops its new structure(Kocmanova A at al, 2012). Yet OECD uses 2 additional tools for ESG analyses, for regions being under transition. The 2 models, based on commercially available ESG ratings from major power providers, therefore, ESG portfolios ratings could exhibit superior risk-adjusted returns and mathematical formula is given below (Markowitz modern portfolio theory).

$$\sigma_p^2(\mu) = \frac{A\mu^2 - 2B\mu + C}{\mathrm{AC} - \mathrm{B}^2}$$

where: A, B, C=Optimization parameters and μ=expected return vector. ESG ratings combine a wide range of metrics impact on climate and climate-related factors able to prevent the transition risks across nations, regions, and firms.

Table 109. ESG metric indices based on OECD ESG model before and after energy transition-evaluation way:1= low, 100=high.

Energy Systems Group – ESG - qualitative indicators	Before Transition	After transition
A. The 12 environmental factors/practices evaluated to help in shaping ESG indices		
Pollution emission levels	75	5
Adoption of Environmental Management and Compliance Systems	45	95
Saving natural resources, improving the efficiency of the use of water resources	40	95
Energy saving in every stage	35	95
Design of special areas for waste and its recycling	32	97
Improvement of efficiency when using chemical fertilizers	45	98
Development of the market of products, chemicals, and biologically based materials	40	90
Eliminate or reduce the use of ozone-depleting substances	60	100
Reduce the adverse effects of production and waste management.	38	94
Improve competitiveness in conditions of rising resource prices and improve efficiency in the use of resources by enhancing innovation	50	85
Protection of the environment through new sustainable technologies	35	100
Use and production of chemicals in ways that lead to minimizing significant adverse effects on human health and the environment.	70	5
B. The 5 social factors/practices evaluated to help in shaping ESG indices		
Working environment, hygiene and safety, education, and training programs in sustainability	60	95
Promotion of achieving a balance between employment and leisure time	60	90
High wages and benefits for whose promote sustainable culture	35	80
Actions to improve the level of skills of employees in sustainability, programs to support technological changes in relation to energy and the environment, equal opportunities development	45	90
Design and implementation of a modern code of conduct.	50	85
C. The 3 Governance factors/practices evaluated to help in shaping ESG indices		
Compliance with laws and practices that support democracy and laws	70	95
Consolidation and dissemination of best practices related to honest methods of economic operation	45	90
Avoidance of actions that result in immoral conflict of interest	70	95

Source: DIPAE/ATEI/2015: Adhoc field research among 243 SME's established in REMTH, made by postgraduate students in the course "Management of Innovation and New Technologies" adaptation and compilation for REMTH by author.

So, the ESG introduction to REMTH's transition process, automatically generates sustainability reports based on international standards (TCFD, GRI, CDP) and national practices (ATHEX-ESG), gives rich reporting (dashboards, KPIs, indicators), links ESG data to financial ones, offers transparency, collaboration and real-time traceability and increases adaptability to REMTH's needs. Regarding the ranking of Greece/REMTH in global basis, based on ESG indicators that are the key for attracting green investments, it is ranked in 28th position, gaining in average terms a score of 52,60 points with max 100. It has the same rank, according to Climate Change Performance Index-CCPI, results of 2020. The next table is one of the most useful since it shows whether REMTH carries out GHG principles, mainly nowadays and future GHG emissions-from 2000 till 2050, based on transition plan as it is presented to previous.

Table 110. Impact of ESG principles on basic criterion of transition, expressed as CO2 emission in tons.

CO2 sources	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Power of E.S in MW											

NG/CCGT in MW	486	486	486	486	486	486	486	486	486	486	486
RES in MW	12,3	27,6	208,3	986,5	1.395,4						
Hydro -power	486	486	486	486	486	486	486	486	486	486	486
Fossil fuels	3,52	3,83	3,37	2,92	2,81	2,76	2,40	1,80	1,76	1,44	1,22
Industry	0,41	0,33	0,24	0,21	0,16	0,13	0,13	0,11	0,09	0,10	0,08
Homework sector	0,32	0,39	0,39	0,36	0,37	0,40	0,40	0,37	0,30	0,24	0,16
Services	0,003	0,006	0,005	0,004	0,005	0.004	0,004	0.004	0,002	0,002	0,001
Agriculture	0,11	0,13	0,13	0,11	0,10	0,10	0,09	0,08	0,07	0,05	0,03
Transportation	0,86	0,96	0,94	0,95	0,96	0,96	0,96	0,81	0,70	0,52	0,44
Power production	1,76	1,85	1,55	1,17	1,08	1,06	0,68	0,46	0,47	0,43	0,44
Rest energy sector	0,12	0,15	0,11	0,10	0,08	0,07	0,07	0,04	0,03	0,06	0,04
Not energy sectors	1,26	1,27	1,0	0,82	0,81	0,81	0,77	0,71	0,64	0,53	0,50
Industrial processes	0,32	0,32	0,40	0,20	0,24	0,26	0,24	0,19	0,14	0,00	0,00
Other emissions	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GHG emissions exempt CO2	0,94	0,94	0,74	0,62	0,59	0,57	0,52	0,49	0,48	0,49	0,53
Total emissions	8,36	10,17	8,71	7,40	7,20	7,06	6,26	5,06	4,68	3,94	3,44
Overtime changes %	100,0	121,6	101,1	88,5	86,2	84,4	74,8	60,5	56,0	47,1	41,1
Overtime changes %	100,0	121,6	101,1	88,5	86,2	84,4	74,8	60,5	56,0	47,1	41,1

Source: RAE report 2020, IENE report 2020.

8.13. Conclusions

In this part of the monograph we presented a well-documented roadmap-ten steps through which REMTH will be transited to a new technoeconomic environment where, almost the total production and energy systems, will produce almost zero GHG emission. From the point of view of economy, climate change is a negative externality for REMTH, initially increasing the production cost to almost all sectors, and later this negative externality should shift in a qualitative competitive advantage. In fact, we tried, through a roadmap to contribute to a realistic, successful, and cost-effective transition to a full decarbonized regional economy. The final outputs from the optimal power mix with the max benefits and least environmental social and economic costs in transition process are:

Table 111. Summarized outputs of transition process.

Transition projects	**Today conditions - 2021**	**Future conditions- 2050**	**Upgrading conditions**
Total power MW	1.972	5.570	Increase by 182,4%
NG unit MW	485	0,0	Stop
Hydro MW	486	500	Increased CF
RES MW	1.001	5.070	New installations
Total power production MWh	4.996	16.320	Increased CF+MW
Power production GWh from NG	1.400	0,0	Stop
Power production GWh from hydro	920	1.220	Increased CF+MW
Power production GWh from RES	2.676	15.100	Increased CF+MW
Power demand GWh	2.850	6.412	Increased electrification
Power peak			
Power nadirs			
GHG emissions in tons	532	12	Closed NG unit
Contribution of energy sector to GDP	6,2	9,5	Greater implication of energy
Investments to transition projects	2.457.000.000	9.876.000.000	Many transition projects

9. Sub-Part D: General Conclusions, Critics, And Comments About Remth's Transition Roadmap

9.1. Transition in REMTH: a tectonic adjustment of all parameters to its new ES

The required transformation of the energy sector is extensive, involving a global dimension and covering the entire spectrum of the chain. Critical components that need to be adjusted even in regional level-such REMTH-include:

1. Infrastructure, with the main challenge of upgrading existing networks, which often have outdated features, and digitizing them-smart management and meters.
2. Energy production, based on advance technologies with an emphasis on RES, energy savings and storage- NG to be used as a bridge fuel till 2045.
3. The inclusion of clients in production portfolios is not only a means of verticalization and hedging, but also a factor of flexibility, through the demand response.
4. The retail market, where the combined services dominate, electricity, NG, energy efficiency as complementary technical and digital dimensions.
5. The design of REMTH's energy markets, with new structure and products, in order to adjust the positions of the participants in successive time scales, to reveal the value of individual services-flexibility and balance-and to establish equal treatment of production and demand response. At the same time, as RES squeeze in wholesale prices, there is often a need to compensate for the availability of reserve units-the flexible NG/Hydro, which are necessary to offset the variability of RES, but may have limited operation. The new European framework excludes polluting units, such as lignite, from the above support schemes.
6. REMTH's prosumers, who will now be entitled to carry out, directly or through aggregators, a wide range of activities, individually or collectively. It means they will be able to produce/sell/store electricity from RES, have smart meters and participate in energy communities.
7. REMTH will have to be become more innovative, introducing technologies that significantly reduce the cost of RES and store systems, allow electric cars to supply power to the grid and highlight H2 production and CO2 capture applications. The transition time from pilot to large-scale applications and the rate of cost decline will catalyze the role of individual approaches.
8. REMTH will have to boost the synergies between economic sectors and to the optimal utilization of existed and new infrastructure. Transportation, water and waste management, buildings, smart cities, and land use need to be combined to contribute holistically to reducing pollution in the region.
9. REMTH's RES producers will contract much more often bilateral purchase agreements with large consumers corporate PPAs. These solutions will ensure investment stability, helping to reduce the energy footprint of energy-intensive companies.
10. Apart from the labyrinthine bureaucracy of licensing RES projects and the complexities of spatial planning, on which significant simplifications are immediately expected in REMTH, a critical parameter is the acceptance of local communities. Energy communities, which make local involvement more direct and the benefits of local action clearer, can strengthen consensus

9. 2. H2 and REMTH: Strategy for the best production and distribution systems

EU experts estimate that H2 will be key fuel leading 273 European regions to a zero GHG emissions. H2 should be used as an alternative fuel for transport, exempt EVs, in remote areas strengthening alternative tourism turn such areas into green destinations through financial projects by EU initiative "HECTOR". H2 can be used as, a green fuel since does not emit CO2, as a means of energy storage and for many other useful potential applications in the fields of industry, transport, and buildings. Today, the amount of H2 used in the EU remains limited and the majority of it is the so-called grey H2 produced through coal process. In contrast, the green H2 will be that will dominate for many qualitative and cost reasons-the figure below presents the basic production method and its key-cost components. According to International Hydrogen Council, H2 could potentially meet about 8% of the global energy demand (GED) and all production methods cost about 7.50 €/kg in average terms. The production cost is predicted to be reduced to 1,80-2,5 €/kg by 2030 to meet the GED by about 15% . Relative works estimate the production cost for existed technologies as in table below.

Table 112. Methods of hydrogen production with their cost and production efficiencies.

H2 production method	Capacity factor %	Cost €/kgr	Better match % to REMTH's conditions
Electrolysis	60-80	10,0	95
Thermolysis	20-45	7,5-8,0	-
Photolysis	0,06	7,5-9,0	-
Dark fermentation	60-80	2,2	--
Gasification	30-40	2,4	-
Photo fermentation	0,1	2,0	-
Steam reforming	74-85	1,3-1,5	-
Pyrolysis	35-40	1,2	-
Indirect bio photolysis	-------	1,9	-
Direct bio photolysis	-------	4,6-9,5	-
Solar thermal electrolysis	-------	7,5-8,0	5
Solar thermolysis	-------	7,3-7,7	5
Wind electrolysis	-------	5,3-5,7	5
Photo-electrolysis	0,06	9,6	5

Source: Kumar S.S, Himabindu V(2019) "Hydrogen Production by PEM Water Electrolysis—A Review" Mater. Sci. Energy Technol. 2019, 2,442–454-adaptation in €/kgr by author

From the table we conclude that electrolysis is the best method for REMTH, despite it has some limitations associated with the today technologies, requires a relatively large laboratory stage, low durability, and large scale production system. The figure below gives more information about the electrolysis method.

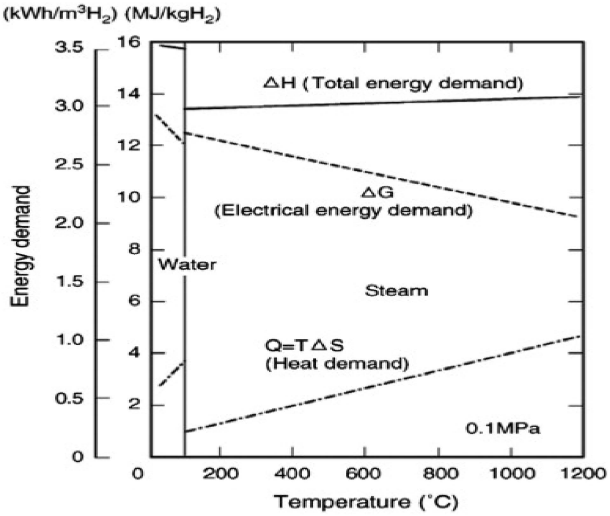

Fig. 31. Water and steam electrolysis energy demand -Source: Reproduced with permission from Elsevier, 2022.

The H2 production installations needs additional distribution infrastructure and the next table describe what type of infrastructure will be necessary.

Table 113. Additional distribution infrastructure for H2 production

H2 distribution methods	**Description**	**Fitting for REMTH 1-100**
Liquefied hydrogen tankers	Cryogenic liquefaction is a process that cools hydrogen to a temperature where it becomes a liquid. If the liquefied H2 is not used at a sufficiently high rate at the point of consumption, it boils off from its containment vessels and as a result, H2 consumption rates must be carefully matched.	50
High-Pressure tube trailers	Transporting compressed H2 by truck, railcar, ship, or barge in high-pressure tube trailers is expensive and used primarily for distances of 300 kilometers or less.	50
Pipelines	Is the least-expensive way to deliver large volumes of H2, but the capacity is limited because today only 1280 Km of NG pipelines existed- 410 km in REMTH are currently available	100

Source: Kumar S.S, Himabindu V(2019) "Hydrogen Production by PEM Water Electrolysis—A Review" Mater. Sci. Energy Technol. 2019, 2,442–454-adaptation in €/kgr by author

EU acknowledging the importance of H2 to fast and cost-effective transition drew a new strategy(2021) aiming to both, to finance the green H2 production through electrolysis using electricity coming from RES and the acceleration of technological developments in RES and electrolysis process performance. Also it acknowledges H2 role in other energy sectors as they are described to below figure.

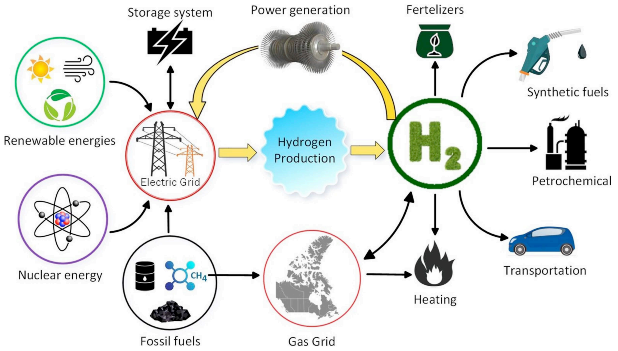

Fig. 32. Effect of hydrogen production on other sectors: Source: reproduced with permission from Elsevier, 2022.

Great challenges emerged to the scaling-up of H2 production in REMTH -beyond the production and distribution methods. In order to be ensured economies of scale H2 production installations will have to be scaled-up, but to this direction there are some barriers that are hindering the production and they are:

- The H2 sector has uncertainties on markets and risks in its supply chain, such as creation of a technological or economic monopoly in H2 suppliers of low-carbon H2 at high cost, and variations in environmental rules within EU.
- Lack of smart chain for clean H2 and it has to be overcome and can support a low-carbon, H2 based economy, although H2 can follow several routes in the field of demand, supply chains, and handling. Therefore, the most viable outcome will rely on the infrastructures and technologies that are involved in production process.
- Lack of cost-effective H2 storage and transportation infrastructure. The techniques for storing H2 are: a. physical systems, liquid H2 tanks, compressed H2 tanks, cryo-compressed H2 tanks, b. chemical systems, chemical hybrids, metal hybrids, sorbents.
- Absence of common EU standards and regulations hinders the diffusion of H2, which restrains the H2 huge potentials. Sooner EU will have to formulate a common rules to prevent unfair competition and free riding.
- Danger flammability since, the dissipation of H2 occurs quickly due to its high diffusion coefficient. Yet, H2 has very small energy barrier of 0,017-0,018 MJ for combustion in air, and a high flammability range of 5–75%, so it burns easily with little source of ignition. The strategy has to be followed by REMTH will have to be based on EU one, but so far it is not existed something clear. The general principles for preparation of REMTH to enter to H2 era are:

- Neutral technology tools that aims at the end-users of H2 and they should be adopted by them. Such neutral technology tools will trigger the demand of H2 in a structural manner and will rationalize infrastructure investments.
- Introduction of tariffs on long-run NG grid, de-risking investments able to boost the uptake on the market to support H2 deployment and infrastructure.

The above strategy envisages a gradual course with phases of development of the economy of pure H2, with different speed depending on the respective production sector.

- **First phase 2020-2025**: goal is to decarbonize the existing H2 production for its current uses such as in the chemical sector and to promote it for new applications. This phase is based on the installation in the EU by 2024 of green H2 electrolytic cells with a capacity of at least 6 MW and aims to produce up to 1.000 tons. In comparison, the total power of electrolytic cells installed in the EU today is about 1 GW.\
- **Second phase 2025-2030**: H2 must become an integral part of the decarbonized ES, with the goal of installing at least 100 MW of green H2 electrolytic cells and producing 10.000 tons. The use of H2 will be gradually extended to new sectors, including steel/process, trucks, rail, and some maritime applications. It will continue to be produced mainly near the uses or near RES parks in local ecosystems.
- **Third phase 2030-2050**: Green H2 technologies will have matured and been developed on a large-scale to reach all hard-to-decarbonize sectors where other alternatives may not be feasible or have higher cost. The question of how H2 supports the “European Green Agreement” is that its widespread use will replace NG and fossil fuels by almost 95%. H2 can support the transition to an ES based on RES, balancing the same time the higher variability of ES due to high share of RES. It offers a solution for the decarbonization of economic sectors based on high GHG emissions fuels and which are impossible to be electrified soon. How H2 can back economic growth and employment is an important issue. Investments in H2 will be a driving force for growth, which will be crucial in the recovery from the COVID-19 crisis. (https://ec.europa.eu/commission/presscorner/)

9.3. Energy transition: final benefits and cost for Greek/REMTH’s societies

The transition to a lower polluting economy is a necessity, not an option. It is revealing that the economic losses associated with climate change have exceeded in 2017, €270 billion worldwide, €41 for EU, €1,4 for Greece and €43 ones for REMTH (Eurostat report 2018). In the energy sector, the essence of the transition is concentrated in the triptych which reflecting three basic concepts, decarbonization of production systems, digitalization of management for energy and decentralization of power production. Undoubtedly, the transformation of the energy sector highlights a range of new opportunities for citizens and businesses, but also important challenges, which we are called to face immediately, comprehensively, and effectively. A crucial issue is to launch the complex adjustments required, in a balanced and coherent manner, so that the resulting benefits gradually offset the costs of the transition. The need for cost smoothing becomes apparent, given that the investment needed to meet the energy and climate targets set for 2030, 2040, 2050 is estimated at €1 trillion across Europe. In Greece , the energy mix has already changed significantly and is evolving at a faster pace in the direction of carbonization. This year 2022, the share of RES in the energy balance has exceeded 23,8%, while NG, which is the "bridge" fuel in the energy transition, rose to 31%, and the share of lignite fell to 15%. At the same time, the National Plan for Energy and Climate(NPEC), which will be finalized within 2022, has already set ambitious targets for 14 GW of RES in 2030 compared to 5,8 GW today-the respect in REMTH are 1,7 GW compared to 0,986 GW today. It is pointed out that, for the year 2020 the amount paid for RES, through the ETMEAR charge on electricity bills, amounted to €976 million. As NPEC envisages more than doubling the share of RES in electricity generation, from 23,8% today to 55% in 2030, minimizing RES support costs is becoming crucial. In this regard, Greece has made reforms, implementing competitive procedures for new RES projects, and linking their compensation to prices in the energy market, to prevent deficits. The RAE has already conducted 11 auctions, in which 1300 MW of projects were awarded -712 MW of photovoltaic and 577 MW of wind, with the lowest price achieved being 185 €/MWh. This is a remarkable development, as the starting prices of the first auctions ranged at 80-90 €/MWh (RAE report 2022). At the same time, while RES subsidies are being reduced or eliminated internationally, reflecting the competition and declining technology costs-yet it does not is in force in Greece, the need for further support of RES arises: a. for flexible conventional units, which smooth out the great variability of t stochastic RES production. for construction of large scale storage units, which attribute the surplus of energy produced by RES to other hours, reducing their outages. It is noted that in our country, the flexibility mechanism, which began to be implemented in September 2018 with a competitive process, had a budget for 2022 of € 220 million while the regulatory framework for storage is being developed (RAE 2022). In addition, the project of installation in Greece/REMTH smart meters, which will allow all consumers to shift their consumption depending on price changes in energy markets, amounts to €1 billion / €54 million respectively. In this approach, it is crucial that the amortization of investment in smart meters, through the network charges (DEDDHE), be done gradually, in order to be synchronized with the savings that will be achieved by the consumers. Energy security, independence initially from oil and gradually by NG , and the further penetration of RES are catalytic importance, but at the same time, the minimization of costs and its gradual fixation in the transport charges (ADMHE) must be ensured. Apart from the labyrinthine bureaucracy of licensing RES projects and the complexities of spatial planning, on which significant simplifications are immediately expected in Greece/REMTH, a critical parameter is the acceptance of local authorities and communities. Energy communities, which make residents involvement more direct can strengthen consensus. Due to possible strong reactions of local authorities and communities, a strong campaign policy should be launched, in order to understand the necessity of installing RES. The over-effort of scientific bodies is not enough for this purpose, but the power of state intervention is required. Unless such an initiative is taken soon by the REMTH , in 2030 its ES will continue to be a "hermitage" of fossil fuels and their price volatility.

9.4. Final conclusions, critics, and comments

To this monograph we dealt in detailed with the great issue of energy transition firstly as a global necessary project and secondly as an example of how a such complex and complicated project can be implemented in the certain region of REMTH. We studied the process of transition from its today economy based by 60% to fossil fuels and high carbon footprint to a new decarbonized one based on RES by 65% in gross energy demand and by 90-95% in power production and consumption and almost zero carbon footprint. Yet, we analysed the actions that will have to do regional authorities and businesses being increasingly committed to achieve decarbonization targets. Greece and REMTH's energy markets face extreme variability driven by geopolitical tensions and a rebound in energy demand after covid-19 pandemic. The energy mix is the key factor for the cost - effective transition where thermal units will have to be replaced by RES till 2050. By 2050, electricity, enabling H2 and biofuels could account for 100% of the energy mix. In other words, to this work dealt the issue of how a region can innovate promoting a cost-effective transition roadmap that will be able to improve its residents' quality of life, its new green competitiveness and increase the carrying capacity of its ecosystems. Defending a new regional sustainable development plan we mean it will be based on three key pillars:

- **Economy**: new green growth opportunities with minimum external costs and clean life cycle of total production system.
- **Environment**: justice in transition so that benefits and costs to be distribute fairly to all citizens, habitants' health protection and least negative impacts to entire human and production systems.
- **Society**: creation of clean anthropogenic environment, creation of new high-skilled jobs, promotion of eco-innovations and consumer protection.

The challenges of our proposed green venture have five key-targets for implementation till 2050, increasing the share of RES in power mix from 35% to 90-95%, saving energy everywhere more than 65% of today level, reducing of GHG emissions by 95-100%, electrification of transportation by 75% and upgrading of network/grid by 90%. Completing these targets REMTH will achieve the optimal transition to a competitive zero-carbon and green/sustainable economy. The today information regarding the energy in REMTH will persuade anyone why a such difficult and complex project will have to be carried out-showing at the sane time the present drawbacks and disincentives of REMTH:

- The high degree of energy dependence from imported fossil fuels. In average terms for the period of 2011-2019 dependence was 67,4% (HELLASTAT 2020), while the average energy dependence of EU-27 was 54,3% (EUROSTAT 2020).
- The 32,8% of manufacturing firms are energy-intensive without any system to save energy improving their cost competitiveness-energy waste is estimated to 63 GWh.
- The 70,8% of existing buildings are energy-intensive, with higher consumption by 64,3% than the average of EU-27, built before 1980 energy waste is estimated to 122 GWh.
- The very low share of passengers and freights transported by train, the more green transport meaning energy saving of 110 GWh
- The very low penetration of heat-pumps and district heating networks to meet thermal needs, meaning energy saving of 44 GWh.
- The small market of energy services 4,5%, comparing to 6,1% of EU-27 (EUROSTAT 2020).
- The great correlation between energy consumption in transport and the domestic sector with the available income and fuel prices, 78,4% and 80,2% respectively (RAE report 2020). The proposed suitable four strategies for the above presented cost-effective transition are given to the next.
- Integrated the well-documented regional energy short-mid and long-term energy planning into transition project.
- Optimization of power mix with the RES share to reach up to 95% by 2050.
- Increase of energy performance and efficiency, mainly in power production and buildings.
- Systematic and well-designed informative campaign so that authorities and local societies to accept and adopt the new energy practices boosting the transition process.

The suggestive indicative tools for a successful implementation of four strategies are ten:

1. Re-organizing and digitizing the energy structure and system.
2. Ensuring the necessary capital sources to finance all the planned projects.
3. Promoting a smart campaign for a greater societal acceptance of wind systems installation.
4. Ex-ante, on-going and ex-post evaluation of transition process through adhoc statistical tools and SCBA capable for determining the optimal power production mix, or the best share of RES in a power mix with the least , or zero GHG emissions.
5. Planning a realistic model capable to promote the gradually electrification in transport, and savings in industry and buildings.
6. Planning a realistic model capable to promote offshore RES-mainly wind parks.
7. Planning a smart model for choosing the best locations of RES installations, micro-sitting issue.
8. Proposing smart financial tools for financing macro/micro grids and tele-electrometers.
9. Proposing smart financial tools for financing smart large-scale storage systems.
10. Proposing smart tools for energy management in all its aspects.

The proposed 30 years long-run transition plan presented here is a very complex and multifactor plan that has 12 innovations referred to well-designed energy projects and infrastructure:

- Smart planning, taking into account the complementarities and synergies of energy sector with the other economic sectors.
- Emphasis only on integrated interventions to every sector, not to fragmentary ones.
- Advance energy innovative technologies related to decarbonized economy proposed to be subsidized very generous comparing to other projects with significant domestic added value.

- Commercially competitive investments in energy proposed to be avoided if they do not promote environment protection.
- Priorities were given to be targeted using mainly local energy and human resources.
- Projects were prioritized through immediate benefits to final energy consumers and with optimal results in the total regional society and economy.
- New smart and low cost financial mechanisms will have to be utilized properly.
- National and regional roadmaps will have to be synergic and complementary.
- Ongoing transition progress in national/regional level were based on objective energy efficiency indicators.
- Predicted direct benefits of transition large-scale projects were based on realistic documents and forecasted results.
- Investigating the long-term relationship between economic growth, energy use and GHG emissions and proposed how this relation can be optimized using Kuznets Environmental Curve KEC
- Knowing that in REMTH the factors being responsible for GHG emissions are: power production 33,5%, transport 17,5%, industry 17,3%, buildings 5,0% and agriculture 6,5% we implemented the Pareto Principle 80/20.

The proposed green investments on adhoc and well-prioritized transition projects based-beyond the Geek NPEC-2050, on the "EU roadmap -2050" principles given below:

1. All principles have to be followed by all member countries after the necessary compilations and adaptations.
2. Sustainability themed investments, best-in-class investment selections and exclusion of holdings from investment universe.
3. Engagement and voting on sustainability matters and norms-based screening.
4. Integration of ESG factors in environmental and financial analysis.

Regarding the necessary investments in projects for an effective transition, they are estimated for REMTH to € 9,6 billion by 2050, in order to be met all the European targets for climate neutrality in the next 30 years. If REMTH continues to invest in RES projects to the same rate as the last decade 2011-2020, then is almost impossible to invest all the €9,6 million-it is needed to be improved its construction capacity in every aspect. Eg, its construction capacity will have to be increased from €135million/year to € 300 million. To this epilogue point it is worth to refer to "Mirasgentis at all" arguments that claims that, "it is better Greece/REMTH to focus on fast direct power supplying alternatives that are cheaper and easier to be implemented than to slower transition. Their objections for slowly transition scenario are based on, the exorbitant prices of new RES technology equipment, the short-term liquidity shortages and the long-term uncertainties that incorporates the highly anticipated hydrogen venture as the form of energy that will dominate in transport and heating in the near future. They openly express their skepticism about to whether the hydrogen projects will be able to completely get rid of the world economy by GHG's, for a number of reasons, from lack of sufficient power capacity and excessively high prices. My opinion is different, and this view has written down to every point of this work, "the faster and greater penetration of RES, the more cost-effective and better energy transition". The conclusion of conclusions, if REMTH does not adopt 100% of transition roadmap for whatever reasons but partially, it will not succeed to transit to a 95-100% decarbonized economy.

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APPENDICES

Appendix 1

Philosophical and practical questions of energy transition

In order Greece/REMTH to meet energy challenges need a new development model, which will be capable to turn the new energy system-zero carbon model-in a modern, resource-efficient, and competitive economy by 2050. Experience to date has shown that Greece/REMTH can respond to a transition that takes into account EU targets tailored to their ownabilities. To this work we deal with senses like, RES, energy-intensity, carbon-intensity, energy performance and savings and upgrading networks/grids. In this context, an effort is made to analyze practical and philosophical questions about the possibilities for an effective transition from Greece and its remote region of REMTH.

- **1st philosophical question: What energy tools are basic for a success transition:** Vital energy technologies need to be developed and promoted to achieve a future zero-GHG emissions for a climate-neutral planet. The core new technologies seem to be RES with high performance, large-scale power storage systems, green H2 and AI. Future power plants will be smart and will have double efficiency compared to 2020. There will be no need for the operator to refer to complex manuals or seek answers through a maze of internet systems as the AI system of future sustainable power plants will communicate all the data to the operator and answer all the questions in real time. At the same time, H2 has long been identified as a key-component of transition.
- **2nd philosophical question: Who will have to pay for the transition cost:** There is a global principal "the polluter has to pay", but it does not implement 100% anywhere. The needed physical and capital resources for transition are significant and represent a substantial scale-up amount of money. Yet, the capital that will be spent is very different in relation to today way. The expenses will have to be reallocated away from high-emissions businesses to low-emissions ones. These reallocation include managing technological uncertainties of investment, managing risks/return trade-offs, driving capital flows to poorer countries. Due this, questions raise of who and how to best pay for the transition. There are various aspects about to who provides the financing, public versus private bodies, and the mix of financing provided by developed and developing countries, how capital is raised, debt versus equity, taxes on polluting firms. Public financing can come through, raising taxes on energy/carbon-intensive firms named carbon taxes, etc. Looking for the optimal approach to financing transition, societies will need to consider to basic factors. 1.who will decide about the needed raise capital at the speed and scale and incentivize the process of this capital. 2. how financing can be the best, following the principles of equity, including what equity would require based on the history of emissions and who is able to pay 3. How it can influence the socioeconomic impacts of a carbon-zero transition. Finally, the question of who pays for pollution is unavoidable for all stakeholders, undertaking the transformation needed for transition to green economy.
- **3rd philosophical question: Can transition support and coexist with the economic recovery:** Yes, transition through the huge necessary investments will support economic recovery and will co-exist with it (WEF report 2021). Strong incentives that will have given to investors in order to invest on absolutely clean energy projects, can serve to both purposes in same time. It means, faster and greater growth, creation of new specialized jobs and, at the same time, gradually installation of sustainable energy infrastructure capable to benefit of the REMTH, the country and the planet.
- **4th philosophical question: the goal of net-zero emissions will require a transformation of the entire spatial economy, or only some sectors linked with energy:** Effective decarbonization process means, shifting the energy mix from fossil fuels to RES by 95%, adapting industrial and agricultural methods to new growth model, avoiding deforestation, and enabling production systems to save energy greater than 65%, consuming fewer energy-intensive goods, introducing the circular economy principles, utilizing storage technologies, increasing energy efficiency, introducing smart tools for best managing of supply/demand balance, creating carbon capture mechanisms, and enhancing sinks of greenhouse gases. All previous mean that, decision-makers will have to focus on the total economic sectors and not only in sectors linked directly with energy transition. Changes needed in workforce skills and culture.
- **5th philosophical question: will capital spent for transition be characterized as an operational cost, or as cost-effective investments:** The transition's financial impacts and implications overpass the spending on
- physical assets. The impact would be front-loaded costs by 2050, including operating capital and depreciation costs of new and existing assets from 2020 levels. They will be happened for 3 reasons, a. due to investments that will be needed in new RES, grid, and large scale storage systems, producing capital and depreciation costs b. due to some fossil-based power systems would continue to produce capital costs, even if they are under-utilized or in alert situation c. due to more frequency and greater last outages due to very greater share of RES with volatile power production and the unable of the spatial ES to cope with these drawbacks soon, because many new energy infrastructure will have to be done in few time.
- **6th philosophical question: The transition could lead to a better reallocation of labor, creating more direct, indirect, and induced jobs than they will be lost:** McKinsey estimates that every $ 10.000.000 investments in RES can create 75 high-skilled jobs. Every $ 10.000.000 investments for increased buildings saving efficiency create 77 high-skilled jobs. According to a study by EUROACE and the International Labor Organization-ILO, an average of 10 jobs are created in Europe for every € 1.000.000 invested in the energy sector. According to IENA, the most energy specialized institute, predicts that, the energy transition will create 11 billion more well-skilled jobs than those will be lost by 2050 in EU. The diagram below gives a picture about the new jobs created in 5 sectors linked with energy transition.

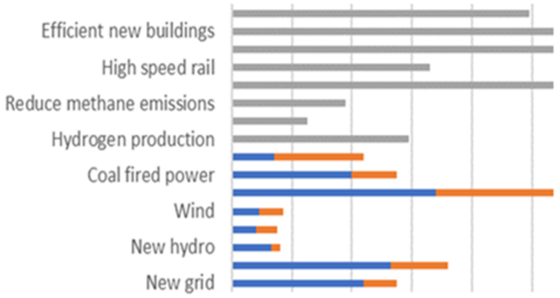
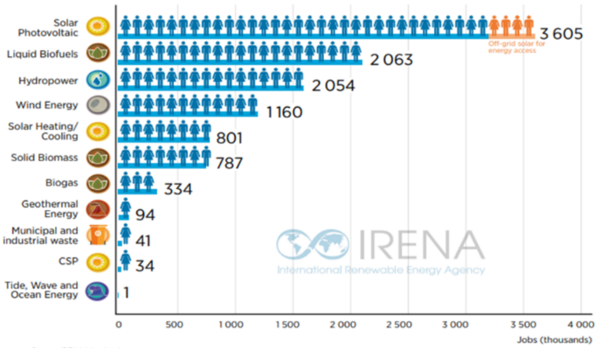


Fig. 33. New jobs created by € 1.000.000 investments in energy (source: IENE 2021).

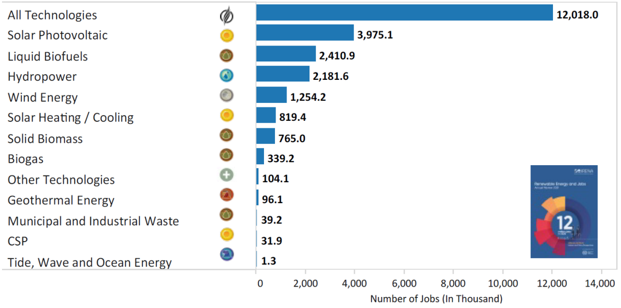
According to IRENA report (2021), the rate of creation new jobs in energy sector during the transition process depends on type of RES technology-The higher, more complicated technology, the more new jobs. The graphs below depict this relation among RES technology and the rate of creation new jobs in energy sector during the transition process.



Source: IRENA jobs database.

Note: Another 7600 jobs, not shown separately here, cannot readily be broken down by individual renewable energy technology.

Fig. 34. New jobs created by types of RES technology investments in energy (source: IRENA:https://www.irena.org/Statistics/View-Data-by-Topic/Benefits/Renewable-Energy/



Source IRENA jobs database. Figures provided are the result of a comprehensive review of primary information sources by national entities such as ministries and statistical agencies, and secondary data sources such as regional and global studies.This is an ongoing effort to update and refine available knowledge. Totals may not add up due to rounding.'Other Technologies' include jobs which are not technology specific.

Fig. 35. Relation among RES technology and the rate of creation new jobs in energy.

IENE and EU experts (2021) argue that "changing the energy model, from the existed based on fossil fuels to a different one based on high performance RES, and energy consumers converted to energy producers and consumer" will be benefited not only the climate and environment but also the revitalization of the economy and employment.

The rate of the job dislocations/lost in the moderate transition scenario have to be compared in perspective with job dislocations/lost from other economic mega-trends, AI, ML, Robotics, automations. McKinsey suggests that automation, remote work, and e-commerce trends could lead to job losses of about 270 to 340 million across eight developed countries between 2018 and 2030, with commensurate job gain, considerably more than it estimates for net-zero transition related job losses and gains globally.

One notable point in Mckinsey analysis of the job gains/losses during the transition would be their focus in specific sectors and geographic regions. Job gains would be largely associated with the transition to low-emissions of production systems, while the losses would particularly affect workers in fossil fuel–intensive or otherwise emissions-intensive sectors. But the complexity of the transition may lead to the reality being more disorderly, and it may not be feasible to limit warming levels to 1,5C. The main-risks are three: **a.** the concerns about the choice of pathway to arrive at zero emissions, and whether this will be smooth or abrupt **b.** the measures taken by stakeholders to ease the adjustments needed for a zero GHG transition **c.** the range of constraints that could prove challenging even if the pathway chosen is a relatively smooth and gradual one.

- **7th philosophical question: Rapidly scaling up energy demand without corresponding scale-up of energy supply, could lead to supply shortages during the transition:** This problem is coped with by the Balancing Energy Market eg, it corrects the imbalance between production/demand in real time. The Balancing Market is divided into the Power Market, the Energy Market, and the Clearing Process System. In Greece/REMTH B.M, the model of Central Dispatch of Power Units is adopted by the Transmission System operator through the execution of Unified Programming Procedures. Participants of B.M are characterized as representatives of Balancing Responsible Parties or Balancing Service Providers. Balancing Service Providers in the context of their participation in the Balancing Market may submit the following bids to the Balancing Service Entities they represent:
    - Up/Down offers of Reserves for Maintaining the Frequency
    - Up/ Down offers of Manual Reserve Frequency Recovery
    - Up/Down offers of Automatic Frequency Reservation
    - Up/Down offers of Balancing Energy

With the liberalization of energy markets, the need for modeling the balance in the energy markets increased the need for new mathematical models that would be able to describe both, the new competitive market conditions and the increased stochasticity due to large RES penetration. The first models that were developed and used extensively, both for the study of market operation and for the development of optimal strategic offerings for energy producers, were the Market Equilibrium ones. These manage to integrate the strategic interaction of competitors in the market and aim to find market equilibrium within the meaning of the Nash Equilibrium point which is widely used in the studies of competing electricity markets. According to Game Theory, the problem of finding Nash equilibrium is a problem involving two or more players, each of whom knows the strategies of his opponents. Under this assumption, the game converges to the Nash equilibrium point which is governed by the following property: no energy participant can unilaterally improve his profit by changing his strategy, while the other participants remain in their strategic decisions corresponding to the equilibrium point . In a market characterized by the usual assumptions that govern equilibrium models (rational behavior, complete and perfect information), and there is only one solution to the problem, participants would be expected to offer these equilibrium offers. Game theory has been shown to be suitable for modeling the energy supply/demand balance of participants in an electricity market.

- **8th philosophical question: energy transition will impact positively on energy poverty:** energy poverty is one of the biggest challenges facing the EU and our country. The question is whether the transition will exacerbate, or alleviate, the problem. A general answer is that energy poverty can be alleviated through income improvement and energy lower prices. The cost reduction of power coming from RES-every 10% of RES share in energy mix , contribute to more than 50% of lower price/MWh, according to Greek P/V Association. So the increased share of RES decreases the per-cent of energy poverty. The risk of falling someone into energy poverty within the EU is twice higher than the general poverty. Eg 26,5% of the EU population suffers from general poverty, while 49,6% suffers from energy poverty (EUROSTAT report 2021). This critical phenomenon also affects REMTH, as a number of 98.400 households from 243.650 total fall in energy poverty. We note that measuring energy poverty meets methodological difficulties, requiring the collection of an amount of data, while, according to the literature, the application of different measurement methods leads to different results, both in terms of energy poverty levels and in relation to which households are characterized as energy poor. By 2008, most energy poverty studies had focused on rural areas. After 2009, many urban households-a combination of different people profiles and an old building reserve, are in energy poverty. Energy poverty has serious social and environmental dimensions, since providing energy to all is a major challenge in tackling climate change and sustainable development, ensuring sufficient energy that will not increase global emissions. To answer the dilemma of whether transition and poverty can be measured accurately and to be coexisted, we can use economic analysis tools such as, the Social Cost Benefit Analysis (SCBA), the Objective Approach (OA), the Expenditure Method (EM) and the Minimum Income Standard Index (MISI). In Greece, 3 energy poverty assessment surveys have been done. Santamouris et al. (2013) conducted field research in 598 Greek households and investigated the relationship between financial crisis and energy consumption of buildings-induced poverty. The analysis showed that, despite the colder winter of 2011-12 compared to the previous year, households consumed less energy by 37,3%. The reasons are, the rapid economic downturn and declining of income. Due to the economic downturn, the family income decreased from € 26.211 in 2009, to € 24.900 in 2010, to € 22.498 in 2011, and to 16,780 in 2018, a decrease of 24,1%. After 2017 many other studies have been done by PAPADA (2017), KEPE and IOBE(2021). All studies on energy poverty in Greece use OA method calculating poverty as a ratio of energy expenditure to household. These trends continue although with a lower rate, according to studies of KEPE, IOBE HELSTAT (2021) and PAPADA (2017.
- **7th philosophical question : countries like Greece use natural, technological, human, and physical resources effectively in order to harness the transition's potentialities:**Many EU countries have opportunities to tap into the transition's potential for growth and secure competitive advantages, through their endowments of technological, human, and physical resources. Such resources are, winds, sunshine, sea-waves, water-falls, well-skilled manpower in energy sector and smart manufacturing companies, all able to produce high tech on/offshore RES. A recent study done by WEF/2020 ranks 115 countries' readiness and their efficiency, or Energy Transition Index- ETI, highlights the long way they have to do in order to achieve the best transition within the desired time/cost horizon but also with the limited negative socio-economic impact of a hasty transition. The ETI is the average of the two indicators, system performance and transition readiness. System performance provides an assessment of countries' ES in terms of their ability to support economic growth, accesses the energy supply security and reliability and environmental sustainability. Transition readiness assesses the presence of a favorable environment for the ES to be able to meet the requirements of the transition. Energy readiness takes into account political stability and the level of political commitment, the investment climate and access to capital, the level of consumer participation, the development and adoption of new technologies (WEF, 2020). The histogram below gives a picture about the ETI of 28 counties.

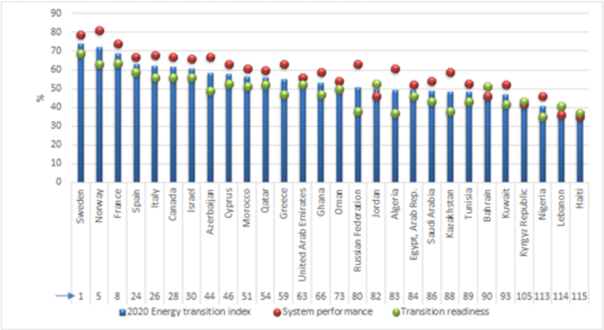


Fig. 36. Energy transition readiness of 28 large energy consumers – Source: WEF report 2020.

Appendix 2. The 5 types of countries according to how they face the energy issues and transition

10th philosophical question : Which countries, based on the common nature of their transition exposure can transit more cost effectively: The features of pioneering in transition countries are, high ETI, large scale capacity for storage power from RES, political stability and commitment, best economic/business/investment environment, easy access to cheap financial sources, high level of consumer participation in social movements, and high acceptance/adoption of new ideas and technologies (WEF, 2020 report). Developed countries based on literature and experience, have a higher percent of these characteristics. According to this assumption, developed countries can achieve faster and more cost-effective transition rates. Yet, the transition to a low-emission economy is increasing demand for certain new skills in the workforce that are more prevalent in developed countries. Also, the greater trend for technological transition, the greater the likelihood of faster energy transition. A model of rapid energy transition, based on decentralized production and consumption of energy resources, necessary to achieve ambitious environmental goals requires significant resources that only developed countries have (WEF 2020, “Fostering Effective Energy Transition 2020 Edition”, Switzerland

Table 114. The 5 types of countries according to how they face the transition.

Type of country	Features of socioeconomic situation
1.Fossil fuel resource producers	Fossil fuel resource producers account for a significant per-cent of GDP ranging from 3% in Australia to 39% in Kuwait. Middle East fossil fuel producers have relatively low levels of carbon intensity associated with their oil and gas extraction/refineries and have relatively lower costs. Due to previous, they should be the last standing providers of the remaining fossil fuels needed during the transition period
2.Emissions-intensive producers countries	To these countries at least 18,5% of their GDP comes from, high-emissions manufacturing firms, fossil fuel–based power units, and classical agriculture sector. Employment tend to be concentrated in agriculture sector, more than 20% while more than 35% of their capital stock is in manufacturing and fossil fuel–based power. These countries should likely adjust to the energy transition mainly by decarbonizing industrial processes, expanding RES capacity, and helping farmers to adopt low GHG emissions practices.
3.Agriculture -based economy countries	Agriculture is the basic sector of employment and income for the majority of the population in these type of countries, accounting for up to 55% of jobs and up to 30% of GDP. A key-adjustment for these countries will be adopting low-emissions farming good practices, which would require mobilizing millions of citizens. Many of these countries are expected to invest in new assets as they grow their economies, particularly related to the power sector securing financing should be a key priority under a net-zero transition. Also these countries have high potential to exploit solar power
4.Land-use-intensive countries	Countries that have reached the early or middle stages of industrialization, the agriculture and forestry sectors together represent, up to 5% of GDP, employment up to 10% jobs and capital stock up to 5%. They should have to balance land-use needs with the best protection of forests and should have to support communities whose livelihoods depend much on them. The contribution of other sectors such as fossil fuel production, power, and industry to GDP, jobs, and capital stock is also sizable for some of such type countries. These countries should have growth potential in sectors such as RES, minerals needed for the transition and forest, reforestation and afforestation projects should generate valuable carbon credits and ecosystem services.
5.Downstream-emissions manufacturers.	These middle-to-high-income countries relate to the manufacturing of goods with high added and technology value, such as automobiles and industrial machinery, that should experience falling demand in their current form because they use fossil fuel–based energy for cost competitive advantages. This type of countries should manage their exposure to shifts in demand for these products by reinventing goods and supply chains. Many make large investments in R&D, which support them well to develop and commercialize low GHG emission technologies.

Appendix 3: Types of RES and their adhoc contribution to qualitative and quantitative benefits

The benefits from the introduction of RES are, clean energy, economic, social, environmental, technological

Table 115. Types of RES and their adhoc contribution to qualitative and quantitative benefits beyond the pure environmental.

Benefits of RES	Type of RES	Brief description of benefits
Pure energy	P/V, Wind on and offshore	The energy benefits from the use of RES for Greece, which energy production is based on domestic but polluting lignite and on imported oil and NG, are many and specific. The dependence on imported fuels is reduced by their gradual replacement by RES, thus reducing the country’s energy dependence. Increased energy dependence makes the country more insecure, but also vulnerable to geopolitical turmoil and changes that occur frequently.

Pure economic	P/V, Wind, Biomass, geothermal	Increase of investments in RES by utilizing existed production facilities, creation of new companies in the RES sector, improvement of the country's trade balance, possibility of private investors in the production of energy and energy products that was not previously possible, promotion of regional development by creating many small and medium power generation companies in various remote areas of the Greek region and GDP growth due to RES energy production.
Pure social	Biomass, geothermal	Creaction of new jobs for the construction, operation and maintenance of energy production facilities and energy products from RES, creation of RES utilization companies in remote areas with few alternative growth opportunities, creation of biomass production, processing, and standardization companies and geothermal for energy use.
Pure technological	P/V, Wind	Utilization of RES P/V and Wind turbines through companies producing products related to RES sectors, promotes innovation and new technologies in the energy. The creation of companies in the field of RES contributes to, the increase of R&D in these fields, to the increase of scientists/engineers in new energy technologies and ultimately to the increase of innovations in the field of RES. At the same time, the promotion of investments in new energy technologies has as a result the technological upgrade of the productive capacity of the country with the creation of modern technological facilities for the production RES systems. Therefore, the use of RES has multiple benefits at local, regional, and national level. Given that drawbacks of using RES are minimal, their further development in Greece is the only way today. All that remains is to find the optimal distribution of the burdens that will be borne by the various social groups at least for as long as financial support is required from the state for the promotion of certain new energy technologies.

Appendix 4: EU/Greece=from the post-digital transformation of their economies to the innovative green transition

The green economy is defined as the economy that produce wealth without making reckless use of natural resources, that is, without harming the environment. It is based on sectors such as RES, green buildings, sustainable transport, good water, useful land, and waste management tools. The green economy and digital technology represent two aspects of modern societies. Digital transformation is a key-priority of the EU, including all the changes adopted by the states and businesses to take advantage of the ITC technologies in order to make the transition more cost-effective. Energy transition projects include digital transformation technologies in ESs, power production/supply and energy networks/grids/ distribution. Today, much of the innovation in the economy is represented by the green economy which, together with digital technology, will lead the EU countries to clean progress. A basic term for success is the degree of ability of countries in producing, introducing, and adopting new ideas and their capacity of implementing these ideas. The Recovery and Resilience Fund (RRF) contains 3 pillars of funding, first for green growth, second for introducing to energy sector digital technologies and third for enhancing social and economic resilience. Regarding the green transition roadmap, the investments plans include, among others:

- Promotion "Energy saving" programs for all and-users.
- Interconnection of the Greek islands which, will significantly reduce the energy costs of all and-users, attract energy storage investments that will allow better utilization of the RES.
- Promotion of projects of urban regeneration ensuring growth and environmental value.
- Promotion of large-scale investments in flood protection projects, accompanied by changes in the use of irrigation networks and installation of telemeters for leak detection and smart water management.
- Promotion of New National Reforestation plans in million stremmas.
- Promotion of initiatives to protect biodiversity, flora, and fauna.
- Promotion of large-scale investments in infrastructure and equipment of the Civil Protection.
- Promotion of adhoc data-centers informing people and organizations about the urban plans under construction and \land use.

Appendix 5: Cost-benefit analysis of renovating/energy upgrading of buildings in Greece

If we take into account that 55% of the buildings in Greece were constructed before 1980 and that the first "Thermal Insulation Regulation" came into force in 1983, we conclude that there is a large building stock that needs to be upgraded to achieve the relevant energy targets. The trend that will prevail in the coming years is the energy upgrade of existing building stock through extensive renovations. This is expected to give a significant impetus to the construction industry, both in terms of workload and employment of skilled labor. Building renovations have many benefits in addition to saving energy. The most relevant are captured below in the table. (European Union 2016).

Table 116. Renovating/energy upgrading of buildings in Greece

Extra Benefits 2020-2050	**Description**	**% change increase**	**Extra costs 2020-2050**	**Description**	**% change decrease**
Economic	Increase employment	0,8	For homeowners	Evaluation costs	1,0

	GDP growth	1,3		Cost of installing new systems	2,0
	Integration of innovation	25,0		Cost of financing new systems	1,5
	Energy security from supplying	55,0		Cost of adaptation to the new energy regulations	0,8
	Increase of energy Productivity	5,0	For tenants	Increased rents	6,0
			For public authorities	Costs for monitoring, controlling regulations by homeowners	23,0
	Energy security	28,0			
	Increase of energy Productivity	35,0			
Environmental	Energy saving				
	Reduction of GHG emissions	95			
	Reduced use of materials				
For home/ premises owners	Increasing the value of real estate	24			
	Health benefits	33			
	Energy bill savings	65			
	Reducing energy poverty	25			

Appendix 6: The role of the public sector in promoting energy efficiency

The public sector although consumes only the 9,8% of energy and is responsible for3,4% of GHG emissions, can play an important role in promoting the energy efficiency of all production systems. It can serve as a model for businesses and citizens to manage the issue of high energy consumption in public buildings and services. HELSTAT estimates that, the activities of the public sector, education, health /social services, public transport, water supply and water treatment and street lighting, account for about 9,8% of final energy consumption. For these reasons, the proposal includes a specific obligation for the public sector to achieve an annual reduction in energy consumption of 1,1-1,4- 1.7% according to 3 scenarios. Yet , Greece is obliged to renovate every year at least 3% of the buildings belonging to all public entities. Public authorities should promote the use of energy performance contracts, especially for large buildings for non-residential use (over 1 000 m2) reducing the energy consumption by 45% and emissions by 65%. To remove barriers to concluding energy performance contracts, the state must set up one-stop shops and consulting services, supporting Energy Service Companies (ESCs) and their clients to prepare projects and identify optimal financing solutions. The availability of skills and training for the energy efficiency professions is also important. Therefore, the proposal includes stricter requirements to ensure that these skills are regularly assessed.The figure below gives the necessary saving actions in public premises and buildings for 3 transition scenarios regarding the speed, a mild, a moderate and a very optimistic. Mild will last 30 years, moderate 25 and optimistic 20.

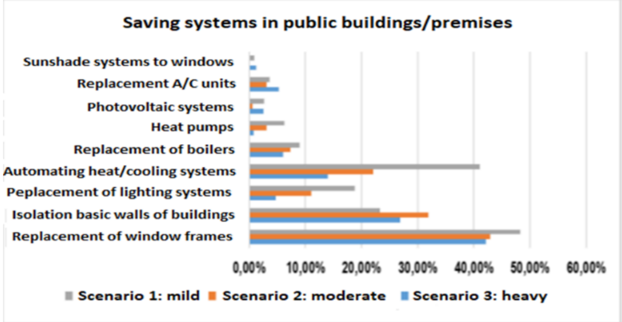


Fig. 37. Energy transition readiness of 28 large energy consumers – Source: WEF report 2020.

Appendix 7: How the risks owed to climate change can affect the financial balance of firms

All firms face the risks and threats associated with climate change, so they will have to plan their strategy and make investment decisions taking into account these risks and opportunities. Also, many firms need to make these decisions immediately, as they now begin their journey to transition to a low carbon economy. The effects of the risks associated with climate change on the outcomes of firms are broad, complex and depend to a large extent on the specifics of each industry-the more associated to energy, the more impacts by transition. The following 10 questions can be a starting point for assessing the impact of climate change risks on the economic performance of Greek firms **(**Source: KPMG, 2021).

1. Firm to undertake the net-zero commitment =10%
2. Firm should know how polluting its production system is=7%
3. Firm should know how exposed it is and to what extent in settings regarding GHG emissions =5%
4. Firm should know how climate change affects production costs and stocks=16%
5. Firm participates in a gaseous emissions program =9%

6. Firm borrows funds for investments in reduction of GHG=11%
7. Firm should finance other firms for investments in reduction of GHG =5%
8. Firm knows what the effects of climate change are on staff costs =4%
9. Firm should know how the projected cash-flow is affected by climate change=24%
10. Firm knows what the disclosure requirements are for climate change issues in the financial statements 9%

Appendix 8: The top-ten trends in energy technologies and innovations

- A new paradigm emerges – RES grow despite higher than anticipated CAPEX .
- Distributed generation consolidates to represent 45% of all new Solar P/V additions.
- Wind technology innovation focuses on larger turbine outputs and new recyclable materials.
- Floating offshore wind reaches commercial scale- wind technology innovation focuses on larger turbines and recyclable materials.
- Supply chain challenges, trade barriers and geopolitics drive new solar P/V manufacturing capacity closer to the en- markets.
- CCUS technologies gains traction as a decarbonization solution for a wider group of regions and industries.
- More concrete policy frameworks open the door for new Hydrogen and CCS investments
- Multiple factors halt the downward trajectory of Li-ion battery costs, with higher prices for energy storage systems set to continue throughout the period after 2022.
- Corporates accelerate their investments in on/offshore RES.
- The period after 2022 becomes a tipping point for Green Hydrogen, triggered by upcoming policy quotas (Source: HIS Markit 2022).

Appendix 9: Pros and Cons of new Law for climate deterioration and transition. Pros and Cons of new climate-law

Pros of new Law:

- Regulations for strengthening the dimension of climate change in the process of environmental licensing
- The bans on the installation of oil burners and the burning of fuel oil for electricity generation on non-interconnected islands
- The proposals for calculation of carbon footprint and emission reduction plans can be considered positive, but they need more clarity and specialization in order to improve their transparency, comparability, completeness, accuracy and ultimately their reliability

Cons of new Law:

- The need for nature protection is not a priority and a component in the effort to mitigate the climate crisis but seems to be limited to vague directions or as a tool in the provisions of adaptation.
- Consultation and participation have not been integrated into the climate law. There is no mention of the need for broad public consultation on critical elements, such as sectoral budgets and the Strategic Islands Framework. Participation in the Climate Dialogue website is limited to certain bodies, while the composition of the National Council for Climate Change is limited and unrepresentative.
- The role of the scientific community in the climate governance system is extremely weak. The law should provide for a body independent of the current political leadership of the ministry, a body for scientific monitoring of the country's/region’s progress towards climate neutrality with strong and substantial responsibilities.
- This contains nothing substantial about the just transition of sectors and regions that will inevitably be affected by climate change mitigation and adaptation strategies. There is no reference to the large and critical chapter of participation in policy-making and just labor transition in all sectors that will be affected by the process of economic transformation.
- No targets for strengthening energy democracy and the role of citizens in producing clean energy for self-consumption. The goal of the REPowerEU project to create at least one RES community in municipalities with a population of over 10,000 by 2025 should be incorporated into the draft law which should be much more ambitious in terms of citizen participation in clean energy self-production. Accordingly, the necessary measures should be adopted to ensure the access of energy-poor and vulnerable consumers to solar energy while strengthening the role of solar strategy, which is virtually absent in this draft law.
- The new law does not provide conditions for the mandatory installation of P/Vs in new public and commercial buildings over 250 M2 by 2026, in existing public and commercial buildings over 250 M2 by 2027 and in all new residential buildings by 2029.
- Absence of legally binding targets that will transform the power generation system into 100% RES by 2035-2040 in terms of environmental sustainability and social justice and will set the basis to overcome technical obstacles to the expansion of the power grid that will host new RES projects. The answer to the question "how many network expansion and storage capacity will be needed to host final RES MW that by 2050 produce 95-100% of power” is "what is needed".
- It is limited to emission reduction plans for municipalities, buildings, and facilities, but without being ambitious in quantity, nor in relation to incentives it targets for citizens and economic sectors in order to accelerate energy savings. Quantitative goals for cost-effective measures, not just reductions in industry and transport, are missing.
- No reference is made to the need for climate and environmental education, both young and old. Every substantial effort to tackle the climate crisis must include education planning that includes all levels and forms of education: formal, non-formal, informal, vocational, and lifelong.
- An area with a significant and ever-increasing contribution to the climate crisis, such as agri-food, is completely absent from the targeting of the climate law, is at best a failure. The gap needs to be filled with the necessary policies and actions combined with the removal of actions in the exact opposite direction.

Appendix 10: was our methodological approach to plan, design and measure the inputs /outputs right and effective

Our approach is designed so that to be able to estimate and calculate the expected Net Present Cost/Value of the transition in micro-spatial basis and to pinpoint the most important factors influencing differences in cost/value. In general, our approach is based on two key planning principles: a.to be included only the least set of variables necessary to accurately represent the local energy system and its evolution under the 3 different scenarios b. to ensure all working assumptions to be technically realistic and as closely tied to empirical evidence as possible. The model analyzes all major energy flows and key- conversions of primary to final power ready for use.

Energy technologies for the cost-effective transition have been selected on the basis of both the empirical verifiability of their current and historical costs, which allows everyone to forecast their likely future improvement, and their ability to collectively approximate all investments and running costs of the local ES.

We exclude the technologies of, co-generation of power/heat, tidal energy, biomass from feedstock and fossil fuel consumption that cover only 7,2% of REMTH's ES. Technologies that are currently small energy players and have not exhibited significant historical cost improvements are also omitted, since contribution was very little. We didn't exclude carbon capture and storage, wind, P/V, solar thermal energy, and geothermal energy.

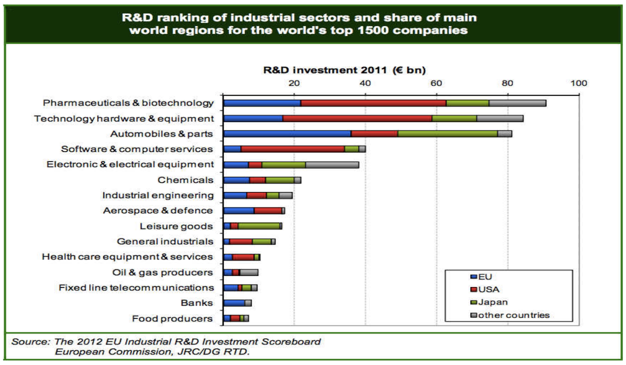
The efficiency with which sectors convert primary energy to useful energy varies dramatically by energy technology. We modelled the transformation process based on average final-to-useful energy conversion efficiency factors as it is proposed by De Stercke (2014). In electricity production technologies, fossil fuels tend to have the greatest GHG emissions-lignite, coal, NG, and the largest transformation losses, meaning that significantly more final energy needs to be produced to obtain a given MWh of useful energy. However, by switching to energy carriers with higher transformation efficiencies, then the final energy consumption can be significantly reduced (Eyre 2019, Lovin's et al. 2019). We stressed to our method the extensive use of efficiency savings in the transition roadmap with the minimum costs.

We planned 3 scenarios-none change, moderate and great change, all are subject to the constraint that they must provide the same total useful energy.

The analyzes tools were, SCBA, Multiple Regression, descriptive and inferential statistics.

Appendix 11: Global Competitiveness Index of energy sector and competitiveness based on R&D intensive

Fig. 38. The 3 axes and 12 pillars of global competitiveness index associated strongly to energy sector-source: WEF



Source: The 2012 EU Industrial R&D Investment Scoreboard
European Commission, JRC/DG RTD.

Fig. 39. R&D ranking of industrial sectors-Energy sector is third in EU-source: WEF.