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Cost Benefit Analysis and Environmental Impact Assessment on PPC's Power Plants Transition from Fossil Fuels to Renewable Resources

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SCHOOL OF ECONOMICS, BUSINESS ADMINISTRATION & LEGAL STUDIES
A thesis submitted for the degree of
Master of Science (MSc) in Environmental Management and Sustainability

January 2019
Thessaloniki – Greece

Declaration

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I hereby declare that the work submitted is mine and that where I have made use of another's work, I have attributed the source(s) according to the Regulations set in the Student's Handbook.

January 2019
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Abstract

Public Power Corporation S.A. (PPC) is the most important electricity producer and electricity supply company in Greece with estimated 7.4 million customers. PPCs have depended almost exclusively on lignite for electricity generation because of the low extraction costs and stable prices however Greece has lannched a legal framework for the enhancement and future development of “green” electricity as the EU legislation and the Kyoto protocol targets demand in reducing CO_2 emissions.

Renewable Energy Sources are becoming an increasing alternative for meeting the future energy demands. Environmental issues, economic benefits but mainly the resource depletion have alarmed the international community and incentivized the use of alternative energy forms. Since policy makers work to guarantee that the electricity sector is trustworthy and affordable, while setting it cleaner and more sustainable, it is critical that they understand the factors which define the costs of power production using fossil fuel or renewable technologies while conducting Cost benefit analysis in order to assess in terms of money the strengths and weaknesses of alternative projects.

Keywords: CBA, Environmental Impact Assessment, renewable, lignite, energy, PPC

Christina Andreadou
31.01.2019

Acknowledgements

In preparation of my dissertation, I had to take the assistance and guidance of some respected people, who deserve my deepest gratitude. Since the completion of this assignment has been satisfying, I would like to express my gratitude to my supervisor Dr Eleftherios Filippiadis for giving me the opportunity to undertake this research and learn about the Energy sector in Greece and the importance of the Cost Benefit Analysis in the decision making part as well as giving me good guidelines for conducting my thesis properly.

Additionally, I would like to express my gratitude to all those who have directly and indirectly helped me in conducting this assignment especially my beloved Ioannis Tziouras who supported me and encouraged me every time I needed it throughout my university studies and inspired me to improve the quality of the assignment.

Last but not least, I would like to thank my family for the emotional, practical and material support that they have given me throughout this year of studies.

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1 Introduction

There has been a booming economic development in the world the last decades which affected the environment in a way that alarmed the scientific communities, the political parties and the people which were either environmentally sensitive or experienced the harmful effects that occurred from the development procedure.

Climate change (also called "global warming") is a fact and the increasing temperatures are inevitable (Morand *et al.*, 2015). Moreover, it is the reason for extreme weather conditions and the change of the rainfall amounts in certain areas (Morand *et al*., 2015) that may have a negative impact on the energy infrastructure as well as the energy system, such as interrupted services due to decreased water availability.

Moreover, the energy sector does not only address the global warming issue but also struggles to highlight problems that occur in the infrastructure sector which is becoming outdated. Therefore, the energy sector is continually investing on innovative technologies, taking into account that the global population is increasing and the energy demands need to be met (Morand *et al*., 2015).

Corporations have solid knowledge of the crucial role they can play in contributing to the climate change goals and this gives them the incentive to operate more effective and efficient. They realize that the climate change poses considerable hazards not only for their operations but also to their stakeholders and therefore adopt climate adaptation and mitigation policies (UNEP, 2012).

1.1 Why study environmental sustainability

Both Governmental and scientific communities believe that Climate Change poses maybe the greatest threat for humanity. Recent studies show that Greenhouse Gas Emissions (GHG) had steadily been increasing the last 50 years. Especially there is evidence which prove that GHG emission reached a peak during the first decade of this century. What is impressive though, is that the above mentioned peak was reached even after adaptation strategies took place (Intergovernmental Panel on Climate Change-IPCC, Climate Change Synthesis Report, 2014).

Mauna Loa Observatory (MLO) presents indexes that depict how the greenhouse gas emissions have evolved since the 1970s. The indexes are based on the observed amounts of long-lived greenhouse gases in the atmosphere and therefore there is relatively little uncertainty.

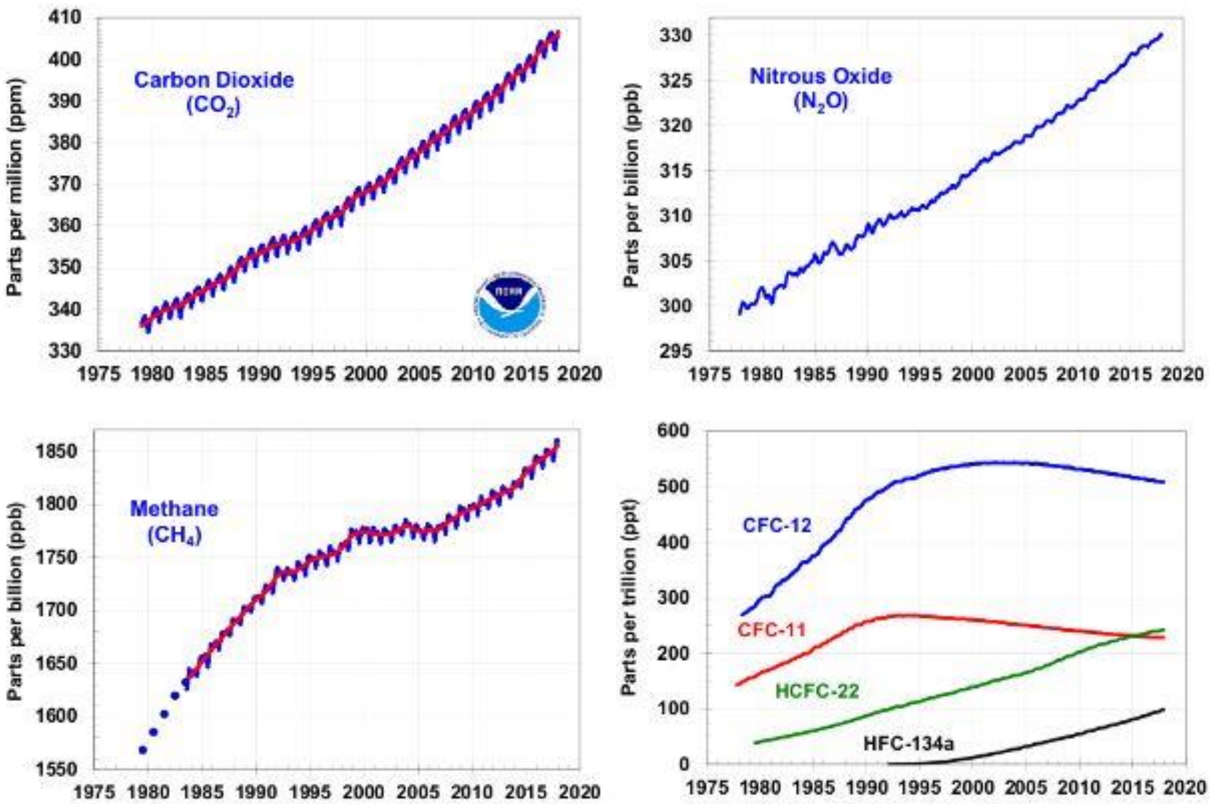


Figure 1: NOAA, Greenhouse gas emissions through the years

(Source: NOAA, Earth System Research Laboratory), Available: https://www.esrl.noaa.gov/gmd/aggi/aggi.html [20 January 2019]

The business sector is the main contributor to humanity's industrial and economic activity and therefore to causing GHGs emissions (Ortar L., 2014). Any fossil fuel when burned releases GHGs in the atmosphere which deteriorates the climate change issue (Tietenberg & Lewis 2012).

According to the IPCC Climate Change Report 2014, “25% of the GHG emissions are produced from burning fossil fuels for electricity and heat production”. Furthermore, the emissions originated from industrial sector are responsible for the 20% of the global ones.

As it is already known, there are emissions that are not related to energy consumption but included in the industrial and construction sector. Furthermore, the amount of the world’s GHG emissions that are caused from agricultural activities, livestock and deforestation is estimated at approximately 25% of the global emissions. Similarly, a big portion of GHG emissions is caused from transportations as Climate Change Synthesis 2014 Report notes.

The figure presented below, demonstrates that households are responsible for producing 6% of the GHG emissions, both for heating and cooking. Energy sector is not excluded from the calculations of GHG emissions. Additionally, as seen below, energy activities other than heat and electricity production are responsible for 10% of the global GHG emissions. Such activities are fuel extraction, refining, processing, and transportation (US Environmental Protection Agency). The numbers mentioned above are depicted in the following figure.

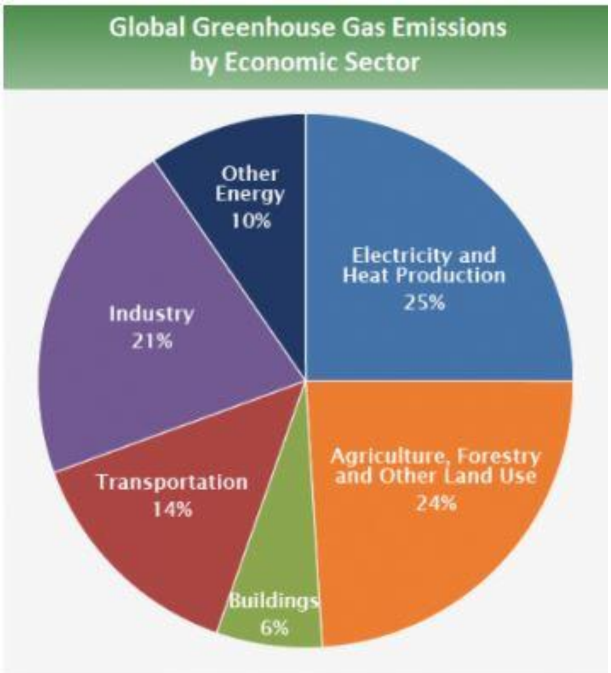


Figure 2: IPCC, Global Greenhouse Gas Emissions by economic sector; based on global emissions from 2010

(Source: IPCC, Climate Change Synthesis Report 2014)
Available: https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf [23 January 2019]

According to the EU's renewable energy directive 2009/28/EC, Greece has to shift to power production from RES up to 20% until 2020 (Nanaki *et al*., 2016). Investments in the wind energy sector are expected to provide the increase of renewable energy resources (RES) capacity whereas part of electricity production will derive from natural gas (Nanaki *et al.*, 2016).

Moreover, apart from complying with legislation and achieving the GHG emission reduction, fossil fuels are exhaustible energy resource and they will turn out to be more expensive in use compared to the renewable ones because the later have lower environmental costs (Tietenberg & Lewis 2012).

1.2 Scope and limits of the thesis

Cost Benefit Analysis (henceforth CBA) and the energy sector are two subjects with a huge bibliography. The present study will investigate the appropriateness and efficiency of shifting from fossil fuel towards renewable energy electricity production. In order to substantiate it, we will be conducting a Cost-Benefit Analysis on the transition from depletable to renewable resources on the Public Power Corporation (henceforth PPC) power plants in the region of Ptolemaida.

There are quite a few ways to adopt an environmental policy in the PPCs power plants. One measure could be to implement a CO2 capture and storage systems to the existing facilities while substituting part of the electricity production with RES, implement emission standards or even low-carbon technologies. If these measures are proved to be insufficient or the financial investment is outweighing the construction of a new facility, then an alternative from shifting to a greener electricity production could be the construction of a new power plant that would meet the standards of an entire green building in the energy sector.

This research is expected to be a cornerstone for future relevant projects relating to PPC's transition to greener resources through comparing the costs and benefits of the alternatives discussed above while taking into consideration realistic factors i.e. the EU Directives, the national economy situation and the private sector's intention to invest in a particular project. What is also expected from this research is which renewable alternative would be the most appropriate for a specific PPC power plant in terms of their Net Present Value (henceforth NVP) outcomes.

2 Literature Review

The energy sector in Greece was characterized by limited domestic resources. Electricity generation in particular is highly dependent on solid fuels with lignite being the most affordable domestic source. The energy landscape in Greece has gone through a lot of changes in the last couple of years (Papanicolaou et al., 2013). This alteration can be attributed to the development of brand new technological improvements and the fact that people are becoming more concerned about the environment. These reasons are very imposing considering the rate at which the country participates in international and intergovernmental unions. There are scientific articles that calculate the footprint of lignite (Juhrich K. 2016), (Piotr Burmistr *et al*., 2016) or predict the CO_2 emissions from lignite combustion (Galetakis *et al*., 2009) which can be compared to the footprint the renewable resources have to the environment (Hertwich et al., 2017) and therefore the transition to a greener electricity production can be documented.

The liberalization process for natural gas and electricity markets through the implementation of the “Law 4001/2011", amplification and expansion of trans-boundary and domestic energy networks, policies of increasing the share of Renewable Energy Resources rather than Fossil-Fuel’s share so that energy production is reformed, improving energy saving and efficiency, boost in protecting the environment as well as being aware on environmental issues, and finally, actions that reinforce competitiveness, are some vital actions need to fulfilled so that the Greek energy market be upgraded to the level attained by other energy markets across the world (Hellenic Ministry of Environment, 2018). Furthermore the bilateral agreements with strategic partners, such as Chinese energy companies, set the issue under a new perspective (Tonchev P., 2017: 5).

The European Union’s (EU) target is adopting policies that will shift the fossil fuel scheme for electricity production towards a renewable energy resources (henceforth RES) one (William J., 2017). In other words, the EU aims in displacing the coal, oil and gas for electricity generation with biomass and waste, hydro-, geothermal-, solar-, and wind power. (William J., 2017). Being one of the EU’s Member States, Greece has set its individual RES goals up to

2020 through its own National Renewable Energy Action Plan in 2009 as well as through its newly presented Greek Energy Strategy that has been submitted in November 2018 in the Greek Parliament for voting.

With reference to the EU (European Commission, Energy, 2012) the issue that is needed to be developed is whether the social benefits are such that shifting to RES for generating electricity is encouraged (Muhammad H. Rashid, 2016; Khan J. & Arsalan M.H., 2015). There are studies that have been made in order to evaluate the energy situation in Greece (Institute for Environmental Research and Sustainable Development, 2017)

In order to assess that, it is necessary to launch a CBA regarding the positive impact of renewable energy use both on the consumers and society. As the main electricity producer in Greece is the Public Power Corporation, (henceforth PPC), CBA should focus on that concept taking into account the transition policies that will support the shift to Renewable Energy Sources more effectively (IRENA, 2018).

3 Methodology of research

The methodology followed in order to present the thesis, included an initial detailed research in scientific pool of bibliography as well as scientific articles in prominent and up-to-dated magazines. Moreover, an investigation on Public Power Corporation's offices or other organization such as, Hellenic Centre for Research & Technology, Hellenic Energy Market Operator, National Center for the Environment and Sustainable Development, etc to took place in order to get provided with any study that has been made before as well as to get provided with representative calculations on CBA for transition from fossil fuels to renewables either on a theoretical level or an actual one since there are power plants that already produce electricity from renewable energy, i.e. wind and solar energy.

In the following chapters, a literature review of Cost Benefit Analysis will take place, the environmental impact assessment of current situation is going to be presented and the evolution of shifting to green energy production will be examined as well as the expected outcomes on the environment after implementing greener measures.

In particular, in chapter four, the theoretical background of Cost Benefit Analysis will be presented with terms of being used as decision making tool. In chapter five, the newly Greek Energy Strategy will be discussed since it is the mostly up-to-dated policy for our county and has been lately submitted to the Greek Parliament for evaluation.

Chapter six includes the current energy infrastructure of Public Power Corporation that is the electricity production in Greece and the means used. In chapter seven, a discussion on the reasons for shifting to greener energy production will be presented as well as technologies or proposals that could be considered as alternatives.

To facilitate the understanding and practical application of CBA in the PPC power plants in terms of shifting to renewable energy resources, in chapter six a case study will be examined in order to provide comparable and realistic outcomes to a certain extent, given that the time the research will take place is restricted. Finally, the conclusions of the theoretical discuss as well as the numerical outcomes of the CBA will be provided.

In the last chapter, the conclusions are going to be disposed. After conducting the CBA for the Public Power Corporation's Power Plants Transition from Fossil Fuels to Renewable Resources comparative assessment of all the benefits and costs from this project will follow in conjunction with the Environmental Impact Assessment of the project.

4 Theoretical background of the Cost Benefit Analysis for energy investments

4.1 The role of CBA in decision making

CBA is a policy method that is used to assess in monetary terms the strengths and weaknesses of different projects while providing a basis for comparing projects (Boardman et al., 2011). It is used to demonstrate alternatives that provide the best approach to succeed the highest benefits with the lowest costs.

As stated in the European Commission's Guide to Cost-Benefit Analysis of Investment Projects, CBA's purpose is to measure "all the benefits and costs of the project to society" (European Commision, 2015: 11). Moreover, it is a real management tool for national and regional authorities as it is "an analytical tool to be used to appraise an investment decision in order to assess the welfare change attributable to it." (European Commission, 2014: 11). This economic appraisal technique, which helps assessing the socio-economic impact, called CBA, according to the Economic Appraisal of Investment Projects Guide of European Investment Bank (European Investment Bank, 2013: 10).

The CBA is also defined as a "systematic process for calculating and comparing benefits and costs of a decision, policy (with particular regard to governmental policy) or (in general) project". Furthermore, cost benefit analysis targets to rationalize the decision making process as well as achieve the most efficient allocation of the common goods (Boardman *et al*., 2011).

4.2 Scope and Steps of the CBA

A CBA is a helpful method because it indicates whether a project or which project should be undertaken, the project's objectives are framed appropriately, a prior and after measures can be developed so as the project can be successful and the required resources to perform the project work can be estimated.

Broadly, CBA has two main purposes:

- to determine whether benefits outweigh the costs through investing in a certain while the difference between benefits and costs is calculated;
- to provide a basis for comparing projects (NPV, B/C ratio etc) – which involves comparing the total expected cost of each option against its total expected benefits (Boardman *et al*., 2011).

However, CBA is methodologically complex. In order to conduct a cost benefit analysis in a way that can be managed, we need to split the process into nine steps which are going to be fully analyzed (Boardman *et al*., 2011).

Step 1 -- Specify the set of alternative projects.

To begin with, in order to decide whether a project should be implemented or not, specification of alternative solutions needs to be determined. To put it differently, whether applying a project is under consideration, what must be defined is in what way that specific project is going to be applied and what costs and benefits is going to occur. A rule that is followed whatever the case is that if the costs outweigh the benefits, then the project is rejected and if the benefits outweigh the costs, then the project can be applied.

In this research, the alternatives are of no concern since there is the Kyoto Protocol and the Directive2009/28/ec of the European Parliament and of the council which Greece has to comply with. The main purpose of turning the lignite power plants to renewable operating ones is to contribute to the targets the Kyoto Protocol and the Climate Change regime mandates.

Step 2 -- Decide whose benefits and costs count (standing).

In this step, who has standing must be decided and this means whose benefits and costs should be included. To put it simply, it should be specified who are the ones that would enjoy the benefits of the PPC's transition from fossil fuels to renewables and the ones that would bear the costs of it. Standing is usually most appropriately specified at a national level. However, the issue of standing is sometimes contagious.

Step 3 -- Catalog the impacts and select measurement indicators.

In this step of CBA, what is required, is the identification of the inputs and the outputs of all alternatives that are suggested. Additionally, these physical impact categories, need to be catalogued as costs and benefits. Finally, each input and output has to be measured.

In this project, which is going to analyzed in the following chapters, there are going to be costs that concern implementation of new technologies as well as operating and maintenance costs. The benefits that occur are from selling the produced product, that is electricity.

Step 4 -- Predict the impacts quantitatively over the life of the project.

However, as mentioned above, we use the term impacts to include both inputs (required resources) and outputs, which in other words include both costs and benefits. As far as the benefits of the transition from fossil fuels to the renewables are concerned, the GHGs and the CO_2 emissions are expected to be dramatically reduced contributing on improving the air quality of the region the power plants are established and consequently the health of the people that live close to the facilities or work in them.

Step 5 -- Monetize (attach dollar values to) all impacts.

There are impacts whose value is extraordinary hard to be monetized because they are not traded in markets (i.e. life). If there is no willingness to pay for an impact, then its value equals to zero.

Step 6 -- Discount benefits and costs to obtain present values.

Dealing with a project that has impacts that happen over years, we must find a way to calculate the total costs and benefits and costs through its lifetime. As we have already seen in CBA, in order to find the present value we must discount future benefits and costs relatively to present benefits and costs. We need to discount them because there is an opportunity cost to the resources used in project and also because people prefer to consume now rather than later (Boardman *et al.*, 2011).

The project we are going to deal with, that is transition from exhaustible resources to RES, is going to be examined in a timescale of 40 years because technology is constantly improving and there cannot be upgrading of it more than specific times over their initial lifetime given.

Step 7 -- Calculate the net present value of each alternative.

The net present value (NPV) equals the present value of benefits minus the present value of costs:

$$NPV = PV(B) - PV(C)$$

The reasonable alternative to choose would be the one with the largest NPV. The proposed project with the highest NPV is representative of an efficient allocation of resources. However, because not every possible scenario is necessarily investigated in the cost benefit analysis, the alternative with the highest NPV cannot be considered as the most efficient allocation of resources.

Step 8 -- Perform sensitivity analysis.

Predicted costs and benefits cannot be monetized precisely because in order to conduct a CBA simplifying assumptions are being made. Sensitivity analysis clarifies for decision makers how these assumptions affect the CBA results. However, analysts usually concentrate on the most significant variables due to lack of time and resource limitations in order to perform the sensitivity analysis.

Step 9 -- Make a recommendation.

After having analyzed all the steps that lead to a successful and correct Cost Benefit Analysis, we conclude with giving a recommendation about the project presented. In other words, the analyst should make recommendations on implementing the alternative with the largest NPV of each alternative. The Net Present Value (NPV) equals with the present value of benefits minus the present value of costs over a period of time. NPV is used in capital budgeting to analyze the profitability of a projected investment or project (European Commision, 2015).

4.3 CBA in the energy sector

CBA is broadly used in the energy sector. For example, the European Commission, in a bid to expedite those infrastructure advancements needed to boost the objectives of the European Union energy policy, released a new Energy Infrastructure regime. The proposed measures comprises of a Regulation for the trans-European energy infrastructure guidelines (Reg.EU 347/2013) where there is already an agreement between the Council and the European Parliament. According to Article 11, adopting CBA methods for gas and for electricity generation is required for facilitating the process of the selecting Projects of Common Interest (ACER Group, 2016: 4).

In addition, corporations have solid knowledge of their crucial in contribution to the climate change goals while complying with environmental regulation and this gives them the incentive to operate more effective and efficient. They realize that considerable hazards are addressed because of global warming which are located both on their operation and their stakeholders so they adopt climate adaptation and mitigation policies (UNEP, 2012).

PPCs power Plants in Greece produce electricity using primarily lignite as a fuel since there are large reserves in the country (Nanaki *et al*., 2016). The combustion of lignite, has a considerable carbon footprint which leads to air pollution if not controlled properly. Greenhouse Gases emissions need to be reduced in order to fight the global temperature increase and this can be achieved by implementing regulations and standards that concern adaptation and mitigation measures in the energy sector. Particularly, the Greek energy system has to adopt strategies that will contribute to the reduction of global warming gases for the period up to 2030 towards the Kyoto targets (Nanaki *et al*., 2016).

5 The newly presented National Plan for Energy and Climate Change of Greece (2018)

5.1 Introduction

Greece recently introduced a new national plan in order to restructure the energy sector in a constantly changing economy full of political challenges as well as declining consumption. On November 2018, the Ministry of Environment, Energy and Climate Change, released the National Plan for Energy and Climate Change 2018 (NPECC 2018).

According to that Plan, developing competitive and price-responsive energy markets is crucial for long-term economic reliability while adopting low-carbon policies in the energy sector (CyprusMail Online 2017).

The Greek government's new energy package proposed measures, focuses on two specific interest areas: 1)the energy efficiency and 2) prioritizing the development of the country's ample renewable energy resources (National Renewable Energy Action Plan-NREAP). The environmental strategies that were implemented so far have achieved the increase of renewable resources in the total energy mix for electricity generation (EIA, 2017) and in the wake of this successful policy, Greece should continue the efforts towards to the utilization of its renewable resources in the non-electricity sectors as well.

As far as the energy efficiency is concerned, a wide range of enterprises have been introduced and implemented lately (National Renewable Energy Action Plan-NREAP). However there is still room for improving and public awareness on the importance of energy efficiency will play a vital role to implement policies successfully while enhancing the funding access (EIA Greece, 2017).

This research examines the ongoing reforms to the support schemes for renewable energy and further motives that Greece could promote to speed up the pace towards the RES transition, without imperiling the electricity security.

5.2 Key characteristics of the new National Plan for Energy and Climate Change

Greece, after many years of recession, begins to shape a prosperity and progress strategy towards an effective exit from the multi-faceted economic, social and environmental crisis, aimed at creating a sustainable and resilient society against external and environmental threats. A crucial stage in this process will be the recognition of the environment and the Greek natural capital as a key element of the country's identity and a central developmental resource. As such, environmental protection is a necessary precondition for a new, sustainable model of production and consumption, laying the foundations for social prosperity, productive employment, fair development and preservation of natural wealth.

The new National Plan has a lot of energy efficiency and renewable energy measures as part of a bigger policy approach on how to reduce emissions. Special focus is being given on energy security and on smart policies reducing operational costs in the energy sector. These initiatives were mostly adopted from the IAE's country report on 2017 (IEA Greece 2017), a report in which the Agency suggested policies that enhance the Greek government's efforts to displace coal with green resources so that the energy sector can be competitive and with low GHG emissions.

5.3 Greenhouse Emissions and Climate Change

The National Plan takes seriously the threats occurring from climate change. According to the Plan, Greece should be more concerned with decreasing greenhouse gas emissions (GHG) across country and gradually modify the existing energy system into a lower-emission one. The quantifiable reduction of GHG emissions until 2020, from all the adopted and implemented measures and strategies are estimated at a level of 34.8Mt CO2eq (UNFCCC). However, the Government has the ability to achieve further reductions, after 2020, through critical investments in the energy sector (European Commission 2018).

To this end, the national plan for energy and climate (NPECC, 2018: 57) is currently follow the premises of the 7th National Communication under the United Nations Framework Conventions on Climate Change (UNFCCC). More specifically, those mitigation measures include a) the development of energy efficiency of electric plants, b) promotion of natural gas, c) investments on renewables, d) a more sophisticated method of waste management and use of biofuels, and e) implementation of energy efficiency measures on households and transportation.

Furthermore, there are measures concerning modifications of the Rural Development Program 2014-2020 aiming to provide newly methods of biological agriculture and biodiversity.

5.4 Water Resources Management

There is also a screening program for the qualitative and quantitative status of the surface and ground waters, the so called National Monitoring Network (National Center for the Environment and Sustainable Development, 2018: 44) which comprises and monitors stations in rivers, lakes and transitional waters, coastal and groundwater. So far, Greece implements successfully the obligations of Water Framework Directive 2000/60/EC.

Regarding the management of water resources, there are some measures concerning the development of water infrastructure (NPECC, 2018: 169) and conservation of water and energy according to a more efficiency management.

5.5 Renewables

Greece modelled its policy framework according to the Renewable Energy Directive (Directive 2009/28/EC) that was launched by the European Union (EU). This Directive aims that the 18% of the total energy consumption will derive from renewable resources by 2020 however Greece decided to be more ambitious and raise its 2020 overall share to 20% (Law 3851/2010). Moreover, the State under the National Renewable Energy Action Plan requirements (NREAP, time frame 2010-2020), set the following targets for the RES contribution to the total energy consumption: (a) at least 20% for converting renewable energy sources down to gross consumption of final energy for cooling and heating, (b) at least 40% for total consumption of final energy and (c) at least 10% for the transportation sector's gross final energy consumption (UNFCCC 2018).

In august 2016, there was a new legislation (no. 4414/2016) introducing a new support program for renewable energy sources. The law targeted at integrating renewable energy sources while encouraging co-generation into the electrical energy market in a bid to introduce an electricity target model starting from 2018 (US Energy Information Administration 2017).

According to NPECC, between 2006-2015, Greece was able to promote electricity generation using renewable energy resources with the help of a FiT programme i.e. Feed-in-Tariff, which contributed in increasing the solar PV evolvent. The term that restricted FiTs for housetop PV applications to only residents that use any renewable energy source like solar thermal to cover some of their water heating requirements has encouraged more people to use renewable energy for covering their heat needs. (NPECC, 2018: 72). This was the reason that triggered solar PV and solar thermal power in Greece (US Energy Information Administration 2017).

The reinforcement of existing measures, in terms with making the process of licensing and permitting uncomplicated, will definitely encourage renewables. Particularly, the wind power will contribute considerably to the diversification of the Greece's energy mix, as the technology costs are being minimized through time. In addition, two more factors that will contribute to the increase of the wind power in the renewable share, is that the historical data of auctions have been competitive and the islands are increasingly becoming interconnected to the mainland system (US Energy Information Administration 2017).

Future goal is to introduce renewables to every sector of energy consumers such as households (heating and cooling), means of transportation, public buildings and industry.

5.6 Energy Security

As seen already, coal is Greece's only noteworthy domestic fossil fuel, though it is gradually loosing relevance due to 2030 targets. Compared to other countries in the EU, Greece's dependence on imported gas is relatively low, though it has managed to double its final gross consumption share in the last decade. Greece is capable to maximize the gas use for heating houses through substituting biomass and oil systems that work inefficiently. According to National Plan, the energy security risk index is near to 70% (NPECC, 2018: 26) and the supplier concentration index is over 45%, which is relatively high.

Coal is the only domestic energy source found in considerable amounts. It is a strategic fuel and through its use about 31.6% of Greece's electricity is produced (UNFCCC, 2018: 62). It is also a very credible source of fuel in the electricity sector, but currently is being unpopular because of the increase in renewables and natural gas shares. However, it is vital for ensuring supply. Greece's margin for system sufficiency is pretty small and derives its flexibility from its liquefied natural gas terminal, which led to supply shortage in the 2016/2017 winter (IEA Greece, 2017: 12). Also, the emergency response plan for gas was very beneficial during the crisis that affected gas supply, with a lot of power producers shifting from gas to oil.

As a result, the new National Plan focuses on a more diverse energy market in order to safeguard the energy consumption at a crisis period. A lot can be taught from the gas crisis that could be implemented in designing the electricity and gas market as well as in forming the emergency gas plan (IEA Greece, 2017: 13). If activation is determined by price signals, demand response is actually an essential source of adaptability in a market where prices reflect the actual value of gas and electricity supplies when in shortage. Interconnections between Greece and neighboring gas and electricity markets will depend to a great extent to the price trends.

For that reason, Greece with its large renewable energy capability, should encourage the utilization of its wind, solar, biomass and geothermal potential to achieve a more balanced energy mix, thereby increasing energy security.

As seen in this figure, amongst EIA countries, Greece's renewable electricity share was close to median in 2016. Greece's entire electricity generation share of solar power was actually the third highest amongst the IEA, while its share of waste and biofuels happened to be the fourth lowest. (EIA, Energy Policies, Greece, 2017)

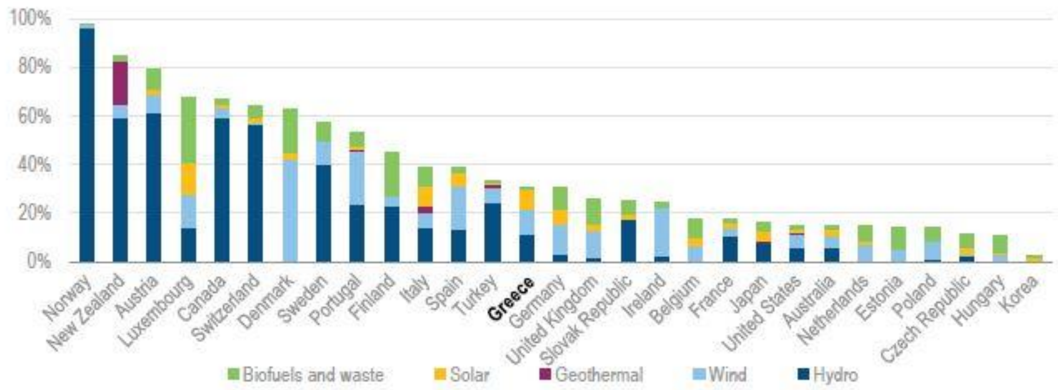


Figure 3: Electricity generation from renewable energy sources as a percentage of all generation in Greece and IEA member countries, 2016

Note: Data are provisional for 2016.
Source: IEA (2017a), *World Energy Balances 2017*, Retrieved from: www.iea.org/statistics/.

5.7 Energy Efficiency

Greece, with the new National Plan, is implementing strategies that motivate or contend sustainability, which thereby contribute to its GHG emission mitigation efforts. The National Plan places a lot of emphasis on energy efficiency. More specifically, there are provisions relative to an energy efficiency compliance project which runs since January 2017. Energy suppliers are required to align their savings with the annual target which is based on the market share of the binded entity (IEA Greece, 2017: 13). Besides, this offers the energy suppliers the capability to work with the industry to identify efficiency opportunities and undertake energy audits, since it complies with the obligation program.

The effectiveness of energy efficiency provisions for buildings has been limited since 2010 due to low reconstruction rate. Therefore, Greece has the capability to enhance its building stock efficiency. Efficiency measures like displacing oil heaters and improving thermal insulation will result in benefits both socially and economically. (NPECC, 2018: 70). For that reason, there are running some national programs and measures under the auspices of National Energy Efficiency Action Plan which can be summarized as below:

- Horizontal measures like, a) information systems to observe obtained energy savings and improvements in energy efficiency, b) Programs designed to financially support research and energy-saving investments, c) Tax relieves for energy saving programs,

d) Implementation of Energy Management Systems in both public and tertiary sectors, e) Bioclimatic upgrades for public open spaces f) Sustainable societies.

- Building measures for tertiary and residential private sectors, like, a) Regulating the Building's Energy Performance, b) Programs designed to encourage energy saving at home, c) Obligatory solar thermal system installation for new residential buildings, d) Giving social housing buildings energy upgrades - 'Green Pilot Urban Neighbourhood' program, e) Mandatory solar thermal insulation for tertiary buildings and f) Enhancing the SMEs that are active in trade, manufacturing and tourism – services.

- Tertiary Public Sector procedures like, a) Integrated energy planning undertaken by Covenant of Mayors and local power, b) Implementation of measures for energy saving for public buildings, c) Initiatives on how to improve the energy efficiency at school buildings, d) green flat roofs for public buildings, e) Mandatory implementation of central solar thermal systems for hot water needs, f) Mandatory displacement of the light fittings with low energy efficiency ones within the public sector and g) Intelligent Nearly Zero Energy Theme Museums.

- Industry measures like a) Relocating companies to business parks and industrial-business zones, b) Innovative Supply Chain, Beverages, Food, Entrepreneurship, c) Green Enterprises d) Support for the improvement of energy efficiency in the business construction process.

- Transportation sector measures like, a) Projects for transport infrastructure, b) Replacing old private and public light trucks, c) Finding ways to replace old private messenger cars, d) Promoting LPG and CNG-powered passenger vehicles, e) Launching electric vehicles and recharging spots for those electric vehicles.

6 Current Energy Infrastructure on PPCs

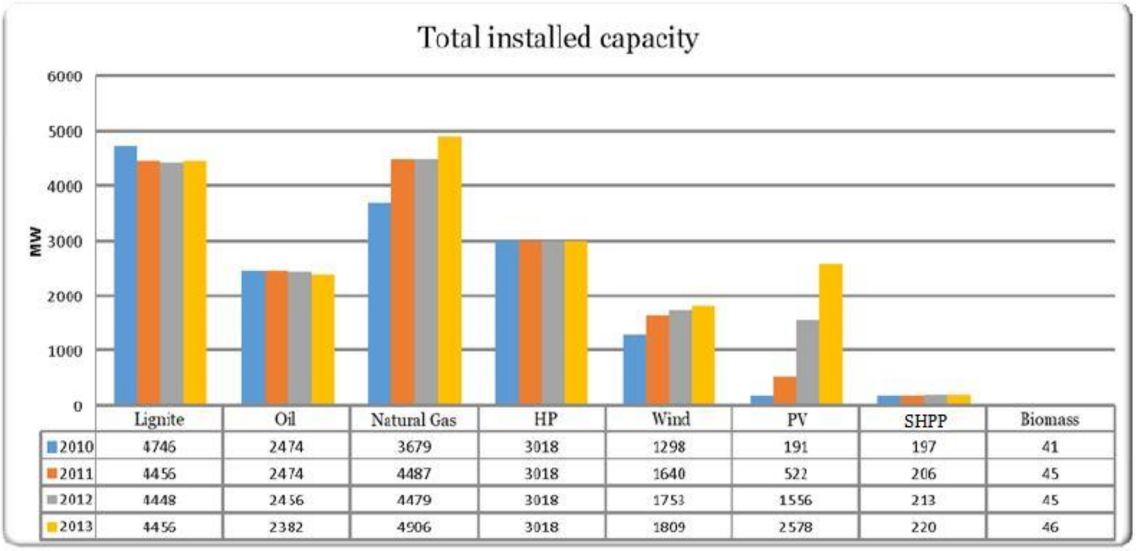
6.1 Description of the electric power system

Compared to the European Union Member countries' energy systems, the Greek energy system is relatively isolated. The reason for this situation is that Greece has a great amount independent island systems and until the beginning of the economic crisis the energy demand has demonstrated high rates of increase (Moirasgentis *et al*. 2017).

Greece's primary energy resources are limited. As a result Greece's energy system depends to a great extent upon conventional fuel imports which are higher compared to the EU standards whereas coal is the basic domestic resource being used almost exclusively for electricity production (Deligiannidis & Angelis, 2007). Moreover, in the 1970s the oil and gas fields that were found proved to be of little significance and swiftly exhaustible (Deligiannidis & Angelis, 2007) while the renewable resources development targets are yet for Greece to be met (Ptolemaida V, 2015).

The installed capacity of net power operation in the mainland is 10.06 GW of which 4.456 MW corresponds to coal energy plants and 698 MW to oil-fired plants. Moreover, there are oil plants located on non-interconnected islands which produce 1.684 MW of electric power. Furthermore, the hydroelectric power of 3GW which is produced by 14 plants and 39 units contribute decisively to the operation system (Ptolemaida V, 2015).

Power generated through renewable energy resources, particularly wind and photovoltaic (PV) systems have recorded noticeable increment in the last couple of years, as seen in Figure 4 below (Ptolemaida V, 2015). In particular, there has been a 46% increment in the installed capacity of the wind systems between 2010 and 2013, from about 1,298 MW recorded in 2010 to 1,810 MW recorded in December 2013, while the PV systems capacity has experienced more increase, to an extent of over 150% annually between the years 2010 and 2012. By the end of the year 2013, photovoltaic system capacity has been more than 2,578 MW27, of which approximately the 374 MW were from the small-scale systems (about 10KW) on around 41,217 housetops. As far as the hydropower plants (SHPP) are concerned, there has been a 23 MW increase amounting to 220 MW, whereas the biomass plants – comprising of mainly sanitary landfill units for gas utilization – amounted to 46 MW in the year 2013 (Ptolemaida V, 2015; LAGIE 2014; DEDDIE 2013).



	Lignite	Oil	Natural Gas	HP	Wind	PV	SHPP	Biomass
2010	4746	2474	3679	3018	1298	191	197	41
2011	4456	2474	4487	3018	1640	522	206	45
2012	4448	2456	4479	3018	1753	1556	213	45
2013	4456	2382	4906	3018	1809	2578	220	46

Figure 4: Installed power data

(Sources: LAGIE, IPTO, HEDNO, Ptolemaida V 2015)

The development of Greece's energy mix has not been significant because of the numerous laws and legislation since they have either decreaced the ensured RES rates or imposed retrospective abatements to them (Ptolemaida V, 2015). However, it should be underlined that the share of energy produced from RES is more than doubled between 2006-2016 and has been recorded at the percentage of 5.9% and 12.5% respectively as depicted on the figure below and this is an element that Greece is on the right path. (EIA, 2017)

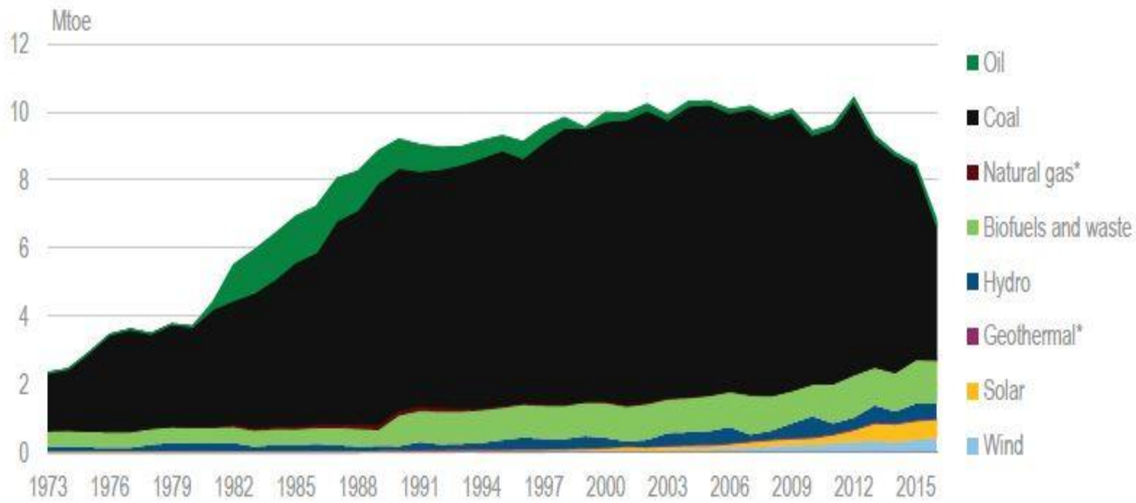


Figure 5: Total share of energy by source

* Negligible.
Note: Data are provisional for 2016.
Source: IEA, *World Energy Balances 2017*, Available: www.iea.org/statistics/. [23 January 2019]

6.2 Analysis of the fossil fuel scheme

The Greek energy sector relies, to a great extent, on fossil fuels, with most of them being imported. In PPCs there are three types of depletable resources used for electricity generation which are going to be analyzed in the following paragraphs.

6.2.1 Lignite

Coal is a significant inland fossil fuel resource, and contributes vitally to Greece's energy security (EIA, 2017) with overall production of 32.3 million tons in 2016 and estimated reserves at 2.7 billion tones (Heinrich Boll Stiftung 2015).

The Institute of Geological and Mineral Exploration (IGME), uniquely explores coal and other mineral reserves in Greece whereas the State of Greece State wholly develops and exploits the coal reserves. Moreover, the PPC is privileged to operate most of lignite mine free-of-charge by the state's permission.

6.2.2 Gas

The importance of natural gas in the Greek economy is noteworthy, with its share of power generation rising to 28% and its total primary energy supply (TPES) rising to 15% in 2016. The consumption of gas in Greece is estimated approximately on 4.1 billion cubic meters (bcm) but the production of it, which was estimated on 0.009 (bcm) in 2016, is very small. Therefore, the country depends on imports, and in particular 65% of them were supplied by the Russian Federation, Algeria supplying LNG comprising of 17% of the entire gas imports, and Turkey held the 16% of their overall imports.

Power generation is a sector that uses considerable amounts of gas, accounting half of the gas consumed in 2015. This has lessened from approximately 70% recorded ten years earlier. The decrease in the consumption of natural gas can be attributed to reduced generation of gas power, which was minimized by more than half from its peak of 13.9 terawatt hours (TWh) back in 2011 down to about 6.8 TWh in 2014. However, there was a rise in 2015, recorded at about 9.1 TWh, holding the 18% of gross electricity produced. The reduction in total power generation, that is 12% fall between the years 2011 and 2015, and the increase in renewable energy sources, that is 81% rise between the years 2011 and 2015, resulted in less gas power production. (EIA, 2017)

6.2.3 Oil

Accounting for half of the gross primary energy supply (TPES) and more than half of the total final consumption (TFC), oil is considered to be the most important fuel in Greece's energy market. In addition, Greece consumes a large oil share in electricity production and the reason for this is that Greek islands are not connected to the mainland's electricity network and therefore are equipped by isolated systems that generate electricity while consuming fuel oil. Furthermore, oil is the main product used in power generation and as far as the total energy produced, oil power stations produced 11% of the gross electricity generation in 2015, the top amongst IEA member countries (EIA, 2017).

6.3 Analysis on the renewable resources scheme

Greece is targeting at reducing the Greenhouse gases while complying with the Kyoto protocol commitments. In order to achieve that aim, the evolution of RES has been a key energy strategy for the country for more than a decade (Kabouris & Hatziargyriou, 2014). The present installed capacity of renewable energy sources in Greece, without taking into account the large hydro, accounts for more than 5.3 GW and in particular, 2.6 GW are installed capacity by PVs, 2.4 GW by wind while the remaining amount is held by small hydro and biomass.

In PPCs there are five types of renewable energy resources used for electricity production which are going to be analyzed in the following paragraphs.

6.3.1 The wind

The P.P.C started using the wind power for power generation in the 80's. There are lots of challenges associated with wind power though. Although a considerable raise in installed capacity has been recorded lately, it is widely agreeable that this raise does not reflect the potential of Greece's wind and the absence of interconnection system within the islands does not favor the wind exploitation. Moreover, wind power is highly dependent on the season making the electricity production per kWh significantly costly. Despite these challenges however, the Greek operator of electricity market (LAGIE) cites the increase of the current installed wind power capacity which is 1.767 MW for the connected grid and 317 MW for the non-connected islands (LAGIE 2018) and this is a result of the constant efforts for exploiting the wind potential.

6.3.2 The sun

The solar power has considerable prospect in Greece since it is a country with massive sunshine throughout the year. In the 1980s the first photovoltaics have been installed by the Public Power Corporation (PPC) basically on isolated areas and particularly islands, so that electricity could be produced and provided to those districts (Martinopoulos & Tsalikis, 2018). In fact, the PP in Kithnos was established in 1983 being a pioneer of this kind in Europe. PPC renewable PV parks account 700kw of the gross installed capacity.

The interest for PVs and their installed capacity has been vertical especially in 2010 when PVs quadruplicated their application in Greece's energy system, beginning from 55 MW at the end of 2009, and ending at 205.4 MW installed capacity at the end of 2010 (LAGIE 2018).

Nowadays, installed capacity for power production from photovoltaic panels is 2.092 MW and 375 MW from PV panels found on housetops and PPC Renewables is about to deploy essential solar power schemes so that they contribute to the reduce of CO_2 emissions (PPC Renewables 2018).

6.3.3 The biomass

There is a considerable potential in Greece's biomass sector which is largely obtainable. Up to 8,000,000 tons of residues may be presumed upon through agricultural harvests like corn, cotton, grain, olive pits, tobacco, etc. per year and further 3,000,000 tons of forest logging residues such as bark, branches, etc annually. Moreover, lots of farmers have shifted to cultivating energy crops, because their potential outweigh the farming and woodland residues in quantity (LAGIE 2018).

There are only few biomass energy ventures that have been developed in Greece. Biomass energy has an estimated installed capacity at 64 MW in 2016 for a total of 12 individual projects which are all located in the mainland while a total of 252 GWh of power was generated by biomass energy plants during 2016 (Energypedia 2018).

6.3.4 Hydroelectric Power

Hydroelectric projects have been largely developed for areas with high potential in Greece. Therefore, PPC has installed hydroelectric power units only on areas that favor this kind of renewable resources and the total established capacity for power production from hydroelectric plants for 2013 is 3.238 MW and in particular from small hydro (<10 MW) is estimated to 220 MW, from large hydro (>10 MW) has been recorded at 2.319 MW while from mixed plants is 699 MW.

6.3.5 Geothermy

Greece holds a rich geothermal capability and although it is suitable for electricity production it remains completely unexploited so far (Vlachou A., 2001).

7 Prospective energy scheme of Greece: Transition to renewable energy sources

7.1 Introduction

The European Union has continuously and actively joined in the worldwide fight against the challenges associated with global warming, over the last two decades (Bitzenis A. *et. al*., 2018: 359). As part of the temporary measures in place for 2020, the European Union has set decisive energy and climate goals, named as 20-20-20 targets by 2020. Commitments to minimize Greenhouse gas emissions from 1990 levels by 20%, advance energy efficiency level by 20% and increase the EU proportion of final energy consumption obtained from renewable sources down to 20%, are some examples of these targets.

As already discussed, the energy market in Greece is experiencing some vital modifications. On the contrary to what was obtainable in the past years, the government has launched strategies, measures and goals to enhance renewable energy exploitation. In terms with its commitments to the EU, Greece intends to boost Renewable Energy Resources (RES) share in total final consumption of energy to 20% by the year 2020. Moreover, renewables are expected to account for 40% of electricity generated by the year 2020 (Bitzenis A. et. al., 2018: 359).

Under these new circumstances, continuous environmental issues and innovative energy technologies as well as demands under international and European cooperation that contain different intergovernmental agreements, are some of the factors that form and balance the Greek energy market's legislative and institutional framework with current ideas and trends. Greece has experienced a raise in electricity generation share of renewables, even exceeding the aims set for solar PVs in 2011. There has been a noteworthy increase in wind power, though below the previously set expectations (IEA, 2017: 14).

It is a well-known fact that Greece possesses a huge amount of solar and wind energy capability, and it has already started attracting investment interests, with a promising geothermal and biomass capability, which continues to remain unexploited. Law 2773/1999 provides that RES electricity is power from plants that exploits: a) solar or wind biogases or biomass, b) Geothermal on the condition that there's a legislation granting the right to utilize geothermal capacity, c) sea, d) Hydro resources comprising of smaller hydro-electric plants with up to 10mw, e) A combination of all the above, f) co-generation utilizing a combination of solar, or wind or biogases. This is why Greece needs to maximize RES contribution on the national energy mix.

7.2 Existing energy scheme for Greece

As already presented, the EU's Directive 2009/28/EC requirements, state that RES will participate in power generation and consumption at least at 18% by the end of 2020. Law 3851/2010, converted the directive to a national legislation whose goal is even more determined than the directive: with 20% of the gross final energy against the directive's

18%. The same law also specifies that the RES must produce 40% of their electricity in 2020, while supplying 20% of the primary energy required for cooling and heating by 2020.

The state's objective is to achieve its 2020 energy renewable energy targets through a range of measures and strategies on renewable energy and energy efficiency, all outlined in their National Energy Action Plan of July 2010. The table below shows the perspective projection:

As of September 2017 the R.E.S. electricity installed capacity by technology was

Table 1: Total installation of RES in Greece (2017)

Technology	**Capacity in Sep 2017 (MW)**	**NREAP Target for 2017 (MW)**	**NREAP Target for 2020 (MW)**
Wind	2,451	5,430	7,500
Solar PV	2,604	1,456	2,200
Small hydro	231	233	350
Large hydro	3,173	3,396	4,300
Biomass- Biofuels	61	160	350
CSP	0	140	250
Geothermal	0	20	120
Total	**8,520**	**10,835**	**15,070**

Source: IEA 2017Available:
http://ekpaa.ypeka.gr/images/Greece%20State%20of%20the%20Environment%20Report%20Summary%202018%20English%20Version_WEB.pdf [24 January 2019]

7.3 Main feature of the new scheme

The Greek Government in August 2016 approved the newly ethnic support project to sustainable production and consumption of energy under Law 4414/2016 which was implemented on the 9th of August, 2016 (Norton Rose Fulbright, 2016: 1).

According to the new RES support scheme, under the Law 4414/2016, the key elements of the new Plan, include the incorporation of EU State Aid Guidelines for Environmental Protection and Energy while it contributes to the achievement of the national energy targets with the optimum balance in relation to social costs and benefits. The main characteristic is the transition of the current electricity market in a new model of the electricity market. But how could it be achieved?

Displacing depletable resources with RES in power production can be accomplished by applying synchronized financial, technical and physical planning actions, complying with legislation, all aiming at taking advantage of the economic capability in order to establish large RES power stations. Penetration of RES in the energy market can also be achieved if all works needed are completed for the electricity network, the establishment of a distributed structure for power generation for new power plants is designed, and the process of gradually decommissioning the inefficient and old thermal plants is facilitated.

According to the National RES Plan, electricity generation share should be at least tripled compared to the 2010 situation so that the 40% target can be met by 2020. Furthermore, the Plan scenario focuses on fulfilling the goals mentioned below with terms of compliance by 2020; the capacity derived from wind power should be about 7.5 GW, jointly with PVs 2.2 GW, solar power plants will account for 250 MW, bioenergy installations are planned to hold 250 MW, small hydro plants 250 MW and finally, geothermal energy should be of 120 MW installed capacity . Also, new installed capacities should be accounted for large hydro plants (350 MW) and pumped storage plants (880 MW), leading overall to a 40% share for renewable energy in electricity production (IEA, 2017).

In order to accomplish those targets, the State increased feed-in tariffs and made the licensing procedures less complex. Moreover, the transmission system operator aims at setting the transmission network capable of accepting high amounts of renewable energy supply. Finally, being the main electicity producer, PPC plans a billion – euro project to be launched in the following years in renewable energy investments (Bitzenis A. *et. al.,* 359).

7.4 Transition to RES

Shifting to a low-carbon economy demands to take into consideration that each sector contributes to different extent and level and therefore the ones with the largest capability should be prioritised to implement the policies for GHG reduction. Moreover, cost-effectiveness and efficiency are two key elements that should be taken into account, especially when assessing those strategies with their associated implementation measures.

The 2050 Energy Roadmap for Greece, which was published in 2012, forms the 2020 plan regarding the energy scheme for the country and embodies the NEEAP and NREAP. In addition, it is considered as setting the initial measures so that RES contribute to 18% for decrease in GHG emissions and total energy consumption. The 2050 Energy Roadmap demonstrates both measures and strategies that may impact on a 60 to 70% reduction in GHG emissions.

The basic constituents of Greece’s 2050 Energy Roadmap are briefly mentioned below:

1. a 60 to 70% GHG emission lowering until the year 2050, contrast with the year 2005;
2. generating from 85 to 100% power production with completely examined or accessible RES technologies;
3. about 60 to 70% RES input to the supply of prime power production until the year 2050;
4. using power production conservation measures and strategies to make energy demand stable;
5. a relative enhance in demand for electricity as a result of the transport sector electrification and increased utilization of heat pumps within the tertiary and urban sectors;
6. less petrol usage;
7. about 34 to 39% enhancement in biofuel usage for transport until the year 2050;
8. 42% of short-route passenger transports through electric transportation;
9. an 18% rise in passengers share and 13% fee transported by train

7.5 Conclusions

The introduction of a new support project for renewable power production is mainly inquired due to the existence of the necessary adjustments in the ethnic support project to abide the Guidelines and to a lower extent by the Greece's energy designing for the further advancement of renewable power production through market based mechanisms until the year 2020. Despite the Energy Roadmap to 2050 which was released by the Ministry of Environment & Energy in April 2012, ethnic energy strategy and the scheme for renewables demand to be reformed by the current situation that is for the medium to long term under the perspective of the progress accomplished so far. Such an updated power production strategy is always crucial for the designing and financing of prime demanding schemes such as power production schemes and transmission infrastructure.

8 Case study

8.1 Introduction

Greece has a history of high CO2 emissions since it has huge reserves of coal. Following the directives of the EU in compliance with the Kyoto protocol targets, our country has to make changes in the electricity production sector. Because the facilities of producing energy are outdated, green technologies need to be implemented in that sector in order for Greece to comply with the legislation. .Lignite mines have billions of metric tons of stock and this makes the electricity production competitive. Establishing Ptolemaida V, the new lignite power plant in Western Macedonia will allow Greek energy market to continue use coal for electricity production while contributing to CO2 emissions reduce since green technologies are implemented. Therefore, business as usual is not going to be examined because any investment to already existing facilities would have been discouraging financially speaking.

In this part of the research a Cost Benefit Analysis is conducted in order to assess the shifting from depletable energy resourses to renewable ones for the PPC's power plants. We are going to compare costs and benefits for electricity generated in the region of Western Macedonia from (i) lignite combustion (taking Ptolemaida V as the basis scenario), (ii) solar energy, and (iii) wind power. Transmission and grid connection costs are not going to be taken into consideration. So, in this case study comparisons plant-level production costs and benefits of installed capacity of 660MW are going to be exclusively examined.

8.2 Methodology

The purpose of these methodological conventions for conducting the CBA is to ensure comparability of the data received while maintain the country-specific information. They are going to be defined in a satisfactory manner in order to be as objective as possible.

The International Energy Agency has publish in 2015 the "Projected Costs of Generating Electricity" and defines key assumptions that should be taken into consideration for energy generating projects for all countries in the European Union. Unfortunately, this manual does not include data for the Greek market, although our country is an EIA member, but for conducting the case study examined in this thesis we are going to assume that the assumptions apply for Greece as well. This assumption is plausible since Greece is an EU member and has to comply to the same legislative framework as all other member states. This framework determines to a great extend the technology specifications for energy production

"Projected Costs of Generating Electricity" published by the EIA provides data for calculating the Levelized Cost Of Energy (LCOE), an index which has not been examined in this dissertation and is not of our interest. Apart from the LCOE, the table below depicts the investment costs, the operational and maintenance costs as well as the carbon costs that occur per MWh in Germany. As mentioned above, because it was hard to collect data for Greece we are going to be using any data needed from this table for sake of simplifying our CBA.

Table 2: Levelised costs of electricity for generating plants in Germany

Table 4.6: Levelised costs of electricity for generating plants in Germany

Technology	Capital costs			O&M costs			Fuel, waste and carbon costs	Heat credit	LCOE		
	3%	7%	10%	3%	7%	10%			3%	7%	10%
	USD/MWh			USD/MWh			USD/MWh	USD/MWh	USD/MWh		
CCGT	6.88	10.95	14.59	7.71	7.71	7.71	83.90	0.00	98.49	102.56	106.20
OCGT	4.37	6.57	8.53	4.39	4.39	4.39	126.15	0.00	134.91	137.11	139.07
Coal – hard coal	9.51	18.03	25.97	9.14	9.14	9.14	48.36	0.00	67.01	75.53	83.47
Coal – lignite	11.89	22.54	32.46	11.07	11.07	11.07	43.08	0.00	66.04	76.69	86.61
Solar PV – residential rooftop	128.10	190.01	242.81	33.46	33.21	33.06	0.00	0.00	161.56	223.23	275.87
Solar PV – commercial rooftop	92.47	137.16	175.27	24.15	23.98	23.86	0.00	0.00	116.62	161.13	199.13
Solar PV – large, ground-mounted	72.96	108.23	138.30	19.06	18.92	18.83	0.00	0.00	92.02	127.14	157.13
Onshore wind	42.49	58.86	72.93	34.67	34.67	34.67	0.00	0.00	77.15	93.53	107.60
Offshore wind	96.97	134.34	166.46	49.33	49.33	49.33	0.00	0.00	146.31	183.68	215.80
Small hydro – run-of-river	77.68	171.98	265.42	41.10	41.10	41.10	0.00	0.00	118.78	213.08	306.51
Large hydro – run-of-river	47.69	105.76	163.41	17.40	17.40	17.40	0.00	0.00	65.08	123.16	180.80
CHP engine – biogas (digester)	35.27	50.28	62.77	32.93	32.93	32.93	0.00	-43.20	25.00	40.01	52.50
CHP engine – biogas	51.63	80.41	103.38	59.74	59.74	59.74	0.00	-51.75	59.62	88.40	111.37
CHP engine – mine gas	22.06	31.75	39.75	28.55	28.55	28.55	0.00	-46.20	4.40	14.09	22.10
CHP steam turbine – solid biomass	81.35	114.93	144.48	41.11	41.11	41.11	106.88	-150.75	78.59	112.16	141.72
CHP geothermal	186.64	290.14	392.66	77.58	77.58	77.58	0.00	-31.36	232.86	336.35	438.88

Source EIA (2105) Projected Costs of Generating Electricity, 2015.

The research that has been made included investment costs of lignite power plant, PV parks and wind parks, operating and maintenance costs as well as prices of selling the electricity produced, CO2 permit prices and costs of mining and restoring.

There are data published on the Ministry of Environment and Energy Operator of Electricity Market wed platforms that refer to establishing wind and solar parks. Because these studies deal with less than 660MW installed energy we are going to multiply the costs that were calculated in the studies so that we have the same power installed to make the comparison. For example, if investment cost for a PV park of 220MW is x the investment cost for a PV park of 660MW is going to be that of the 220MW multiplied by three. The investment cost for Ptolemaida V is published so it is going to be used as it is.

To conduct our CBA we are going to calculate the NPV of each project, using a best/worst case scenario approach. This approach will allow us to have a wider view of all aspects relating to our case and it will help us conclude with proper recommendations.

8.3 Key assumptions

- As mentioned earlier, we are going to focus exclusively on the electricity production. The produced energy is sold in the wholesale market, which remain a source of investment uncertainty. The price of electricity depends on a range of factors of the supply and demand market, included the geopolitical situation, the national energy mix, the import differentiation of energy, the cost of the network, the cost of environmental mitigating and adapting measures, the weather conditions as well as taxes (Eurostat, 2019). Therefore, it is clear that an assumption about the price has to be made in order to have a datum to proceed in our study.

- The price has been continuously changing, so it has been very variable. Data about the price of electricity can be collected from LAGIE and we are using the data average for your calculations.

- The price of electricity produced from RES, is fixed and depends on the auction. We are going to take the data of the latest auction that was carried out in 2018. For solar energy electricity the price is 63,81€/MWh and for wind energy electricity production the price is 69,53€/MWh. (EnergyPress, 2018)

Table 3: Electricity price sales

SOURCE	PRICE (€/MWh)
LIGNITE	54,70
WIND	69,53
SOLAR	63,81

Source: LAGIE, EnergyPress 2018)

- The price of the CO2 permits is located in LAGIE internet page. The average price for the year 2016 was 5.25€, for the year 2017 5.74€ and for the year 2018 was 15.57€. There has been an increase of approximately 173% between the years 2017 and 2018. The target of CO2 reduction is going to be at least 40% from the 20% that applies nowadays according to the factsheet of the European Commission, compared to the 1990 levels as we are going to proceed to the 4th trading period of the EU ETS in 2021. Therefore, projection of the price of the CO2 permits based on historical data is very risky. Because an assumption has to made in order to conduct the CBA for the electricity production by lignite combustion and given that the markets are very interested on the energy sector we are going to double the average price that applied in 2018, that is the price of the permits is going to be equal with 31.14€/tonne of CO2 which is higher than the price the EIA through "Projected Costs of Generating Electricity" that is 26.14€ (30.00USD), an increase of approximately 15%.

- The expected lifetimes for each project according to EIA are:
  Wind and solar plants: 25 years
  Coal-fired power: 40 years

- Because the projects that we are going to compare have different time frames, we are going to use the Roll-over Method.

- As far as the RES are concerned, the prices of electricity that are established from the auction apply for 25 years, that is the whole lifetime of the project. In order to be able to compare our results we need replace the initial investment to have a 40year timeframe. Replacing the equipment causes a cost that equals to 20% of the capital investment according to EIA and a new auction is needed. This means that the price per MWh might be different from the initial one. However, for simplifying our task we are going to have the same price of electricity until the end of the second timeframe.

- The construction time of a coal-fired plant is 5 years while the PV and wind park installation is 1 year.

- The construction cost of Ptolemaida V is allocated within 5 years and it is linear. We made an approach of allocate it by assuming that it would be financed by an organization and it will be similar to loan scheme financing. We will assume that 10% of total cost will be paid in the first year, 15% of total cost will be paid in the second year. The higher costs in such huge projects occur during the 3rd and 4th year therefore we will assume that 40% and 30% will occur respectively during the 3rd and 4th year. Finally, the remaining 5% of total cost will be paid the last year as it is usually the year of pilot operation.

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- The costs of restoring the environment from mining are going to be inserted to the Cost Benefit Analysis every five years because we assume that a proper volume of land should occur from excavating. These costs include transport, working costs but because of lack of published data a realistic assumption by guestimating. The cost that it going to be used is the latest auction the power plant of Aminteo has published, that is 17.000.000€ which will be discounted by 10%, a reasonable discount usually given at auctions. This cost is going to be inserted every five years.

- Another cost that is going to be included in the CBA of the lignite project is the mining cost which is detected in public tables with a price which is not fixed. So, we are going to insert into our calculations an average number.

- The levelised costs of electricity are usually calculated for all technologies for 3%, 7% and 10% discount rates according to the "Projected Costs of Generating Electricity" published by the EIA . We are going to use the same numbers.

- We are going to assume that the capacity of electricity generation is 100%.

- We will assume that the costs for all projects occur at the end of each year.

- In relation to Ministry's of Environment and Energy record regarding electricity sector from renewable resources, the investment, the operational and the maintenance costs are indicated respectively in the following table.

Table 4: Investment, Operation and Maintenance Costs

SOURCE	INVESTMENT COST (€/KW)	OPERATION & MAINTENANCE COST (€/KW)
LIGNITE	2120,00	20%xINVESTMENT
WIND	1310,00	47,00
SOLAR	1750,00	44,00

Source: Ministry or Environment and Energy, Ptolemaida V study

- Based on the study of the project Ptolemaida V, the expected generated power is 4.300,00 GWh.

- Based on the energy balance of Greece (Operator of Electricity Market), an installed capacity of 2 MW of photovoltaics will generate approximately 2.960 MWh per year, therefore the installed capacity of 660MW, annually is expected to produce about 976,80GWh.

- Based on the energy balance of Greece (Operator of Electricity Market), a an installed capacity of 2 MW of wind turbines will generate approximately 3.620 MWh per year, therefore the installed capacity of 660MW, annually is expected to produce about 1.194, 60GWh.

Table 5: Installed and Power Generation

SOURCE	INSTALLED POWER (660MW)	POWER GENERATION (Expected GWh)
LIGNITE	660,00	4300,00
WIND	660,00	1194,60
SOLAR	660,00	976,80

Source: Operator of Electricity Market.

9 Results

This research does not attempt to provide solid knowledge on the costs and benefits that occur from the transition of a general "green growth" program. In order this to be achieved, involvement and resources that go beyond the potential and the aim of this dissertation are demanded.

The methodological approach of this dissertation focuses on whether the transition from fossil fuel to renewable resources is cost-effective as an alternative means of generating electricity. The assumptions that were made were as realistic as possible given that we are proceeding to the 4th trading period of the EU ETS in 2021 and the target of 40% reduce in CO_2 emissions in 2030 meeting the Kyoto protocol commitments. Therefore, the prices are considered very changeable regarding either the CO_2 or the price sale of electricity might be far more different in the following years given that the analysis conducted takes the next 40 years into account. A future approach, after the transition to the 4th trading period may be more realistic because we could use historical data that would occur after the updated targets and market trends.

The main elements from the implementation of the Cost and Benefit Analysis are presented at the following table:

Table 6: Summary of Results of C.B.A.

BASE SCENARIO	SOURCE	LIGNITE	WIND	P/V
	DISCOUNT RATE		3%	
	NPV	1573821423	283305601,3	-458991007,3
	B/C	1,564941889	1,173104103	0,758390903

WORST SCENARIO	SOURCE	LIGNITE	WIND	P/V
	DISCOUNT RATE		7%	
	NPV	-176481902,5	- 144024127,2	-

	B/C	0,90777285	0,8849062	-

SCENARIO BEST	SOURCE	LIGNITE	WIND	P/V
	DISCOUNT RATE	3%		
	NPV	1575124411	475215302,2	35386811,08
	B/C	1,565674191	1,290363897	1,02004379

As we may see at the table above, Net Present Values in producing electricity by Wind and by Lignite in the base scenario which is the expected are positive whereas in the case of Solar energy is negative. This is outcome is quite strange given the fact that according to EIAs latest review for greek energy policies, Greece has overachieved the targets for solar PVs. However, it can be explained because the installation costs are higher from those of wind parks while their effectiveness is lower. The same applies for the price the electricity is sold, that is solar generated electricity is cheaper that the wind's generated one.

Another fact that should be discussed is that according to the same review, wind power capacity has increased significantly. It can be quite a cost effective alternative in the future due to generous feed-in-tariffs that already are being implemented as well as the decreasing technology costs. This fact can be drawn from the CBA that was conducted as well comparing the worst lignite scenario to the best wind scenario.

However, these results are for a 40year timeframe which applies for the lignite case but not for the RES. So, in order to be able to compare these projects we use the the roll-over method supposing we decide to build new lignite power station every 40 years and a new wind park power plant every 25 years so that all projects have the same length in the end, that is 200 years. The case of the P/V is not further examined since the NPV is negative already.

Therefore, we will have the lignite power plant built 5 times and the RES alternatives built 8 times. This makes the projects directly comparable.

So, we have

$$NPV_{(5,\ Ligntie)} = 1.573.821.423 + 1.573.821.423/(1+0.03)^{80} + 1.573.821.423/(1+0.03)^{120} + 1.573.821.423/(1+0.03)^{160} + 1.573.821.423/(1+0.03)^{200} = 1.785.225.819{,}00\ €$$

$$NPV_{(8,\ wind)} = 283.305.601{,}3 + 283.305.601{,}3/(1+0.03)^{50} + 283.305.601{,}3/(1+0.03)^{75} + 283.305.601{,}3/(1+0.03)^{100} + 283.305.601{,}3/(1+0.03)^{125} + 283.305.601{,}3/(1+0.03)^{150} + 283.305.601{,}3/(1+0.03)^{175} + 283.305.601{,}3/(1+0.03)^{200} = 682.576.779{,}40\ €.$$

$NPV_{(5,\ Ligntie)}$ = 1.785.225.819,00 €

$NPV_{(8,\ wind)}$ = 682.576.779,40 €.

It is clear that the lignite scenario after doing the roll-over method, is the most cost-efficient scenario.

10 Conclusions

Greece is currently implementing comprehensive energy sector reforms towards creating competitive energy markets and the increase in the renewable share has been impressive. However, low-cost domestic lignite is still competitive compared to renewable energy resources. The market liberalization that the PPC faces will contribute to a new trends. The construction of Ptolemaida V during the recession has had a positive impact on the financial situation in the region of Western Macedonia and will continue contributing financially in the region since work opportunities will be offered. This social factor, that is employment, has not been taken into account for the CBA that was conducted. Its contribution to the final outcome would have been considerable for the lignite scenario however the research was focused exclusively on the electricity production.

On the other hand, there is disinclination and uncertainty for investing to renewables and displace the lignite because of the recession. Moreover, cost of producing electricity has increased the last years because consumers are asked to pay in renewable subsidies. This is fact leads to negativity towards the green technologies for electricity generation.

This review provides recommendations for further cost benefit analysis approaches since it highlights what further data should be included so that the decision making lead to secure policy improvements and implementations towards a sustainable energy future. Despite the outcomes of the cost benefit analysis that has been conducted in the preparation of this thesis, Greece should and must work on implementing energy efficiency strategies ceacelessly, taking into account other countries' policies.

There is no doubt that the transition to RES will be painful and long. There a lot of actions to be taken such as establishing more cost-effective green technologies so that the costs of investing in RES will be more attractive. Moreover, a way should be found that the prices of the electricity to be fixed so that investors feel secure and turn to RES. This situation is expected to change and be more stable after the transition to the 4^{th} trading period when the CO_2 reduce target will be doubled compared to today's target and the contribution of RES to it will be vital whereas the economic recovery can be an opportunity for initiatives that support sustainable investments

Bibliography

Bitzenis, A. Kontakos, P. Kafteranis, C. (2015). Renewable policies and challenges by 2020 in Greece: A questionnaire survey, Scientia Iranica, 25(1), 359-369, Retrieved from: http://scientiairanica.sharif.edu/article_4407_cf612b783df6842c716132ba8a2406e0.pdf

Boardman, A.E. Greenberg, D.H. Vining, A.R. & Weimer, D.L. (2011). Cost Benefit Analysis concepts and practice, 4th ed., Cambridge: Cambridge University Press

Burmistrz, P. Chmielniak, T. Czepirski, L. Gazda-Grzywacz, M. (2016). Carbon footprint of the hydrogen production process utilizing subbituminous coal and lignite gasification, *Journal of Cleaner Production*, 139, 858-865, Retrieved from: https://www.tib.eu/en/search/id/ceaba%3ACEAB20161011991/Carbon-footprint-of-the-hydrogen-production-process/

Butler, J.H. Montzka, S.A. (2018). NOOA, Earth System Research Laboratory, Annual Greenhouse Gas Index, Retrieved from: https://www.esrl.noaa.gov/gmd/aggi/aggi.html

Deligiannidis, I. & Angelis, I. (2007). Helios Dynamics: A Potential Future Power Source for the Greek Islands, Naval Postgraduate School, Monterey: California

European Comission (2016). The EU Emissions Trading System (EU ETS)

European Comission (2015). Guide to Cost-Benefit Analysis of Investment Projects

Galetakis, M. Vamvuka, D. Roumpos, C. and Pavloudakis, F. (2009). Prediction of annual CO2 emissions of lignite mined from the South Field Mine Greece, 3rd AMIREG International Conference (2009): Assessing the Footprint Resource Utilization and Hazardous Waste Management, Athens, Retrieved from: https://www.researchgate.net/publication/267097430

Kabouris, J. & Hatziargyriou, H., (2014). Wind Power in Greece – Current Situation, Future Developments and Prospects, Retrieved from: https://www.researchgate.net/publication/224652007_Wind_power_in_Greece_-_Current_situation_future_developments_and_prospects

Khan, J. Arsalan, M.H., (2015). Solar power technologies for sustainable electricity generation: A review, Renewable and Sustainable Energy Reviews, 55
Martinopoulos & Tsalikis, (2018). Diffusion and adoption of solar energy conversion systems – The case of Greece, *Energy,* Elsevier, vol. 144(C), 800-807

Moirasgentis, S. Sarafidis, G. Georgopoulou, E. (2017). Long term plan for the Greek energy system, Report, WWF with the collaboration of National Observatory of Athens, Retrieved from: https://www.wwf.gr/images/pdfs/EnergyReportFinal.pdf
Morand A., Hennessey R., Pittman J. & Douglas A. (2015): Linking mitigation and adaptation goals in the energy sector: A case study synthesis report. Report submitted to the Climate

Change Impacts and Adaptation Division, Natural Resources Canada, Retrieved from: http://www.climateontario.ca/doc/reports/Adaptation-MitigationSynthesisReport-FINAL.pdf

Nanaki, E. Koroneos, C. & Xydis. G. (2016). Environmental Impact Assessment of Electricity Production from Lignite, Environmental Progress & Sustainable Energy, July

Ortar, L. (2014). Climate Change and CSR: Can Voluntarism Pay? *The College of Law and Business*, Konrad-Adenauer-Stiftung, Israel, Retrieved from: http://www.kas.de/wf/doc/kas_42648-1522-2-30.pdf?150927101406

Papanicolaou, C. Typou, J. Ioakeim, J. Kotis, Th. Foscolos, A. (2013). The prospect of using Greek lignite in an energy portfolio related to power generation. *Bulletin of the Geological Society of Greece*, 47, 2121-2130, Retrieved from: https://www.researchgate.net/publication/313234755_The_prospect_of_using_greek_lignite_in_an_energy_portfolio_related_to_power_generation

Rashid, M. (2016). Electric renewable energy systems, London: Academic Press Elsevier

Romijn, G. Renes, G. (2013). General Guidance for Cost-Benefit Analysis, Netherlands Bureau for Economic Policy Analysis & Netherlands Environmental Assessment Agency, Hague, Retrieved from: https://www.pbl.nl/sites/default/files/cms/publicaties/pbl-cpb-2015-general-guidance-for-cost-benefit-analysis_01512.pdf

Tietenberg, T. & Lewis, L. (2012), Environmental and Natural Resources Economics, 9th ed., London: Routledge, ch3 pp.46-72, ch4 pp.74-191, ch5 pp.102-117, ch7 pp.140-179

Tonchev, P. & Davarinou, P. (2017). Chinese investment in Greece and the big picture of Sino-Greek Relations, Institute of International Economic Relations, Retrieved from: http://idos.gr/wp-content/uploads/2017/12/Chinese-Investment-in-Greece_4-12-2017.pdf
Vlachou, A. (2001), Environment and Natural Resources, Economic Theory and Policy, Athens: Kritiki Publishing

William, J. (2017). Energy on the Economy,Business.com, Retrieved from: https://www.business.com/articles/the-impact-of-green-energy-on-the-economy/

Other sources (web)

ACER Group, (2016). Energy and Climate Change

Cyprus Mail Online, (2017), Greece praised for progress on energy policies, Retrieved from: https://cyprus-mail.com/2017/11/19/greece-praised-progress-energy-policies/

DEDDIE (2013). Information Bulletin - Production in Non-Interconnected Islands, Retrieved from: http://goo.gl/IccSdx

Directive 2009/28/EC of the European Parliament and of the Council, Official Journal of the European Union, (140) 16

Energypedia (2018). Greece Energy Situation, Retrieved from: https://energypedia.info/wiki/Greece_Energy_Situation

EnergyPress (2018), RES Auctions Retrieved from: https://energypress.gr/news/diagonismoi-ape-poly-hamila-oi-times-gia-ta-mikra-fotovoltaika-kalyteres-gia-ta-megala-sta

European Commission (2014). Guide to Cost-Benefit Analysis of Investment Projects, Economic appraisal tool for Cohesion Policy 2014-2020, December 2014, Luxembourg: Publications Office of the EU, Retrieved from: https://ec.europa.eu/inea/sites/inea/files/cba_guide_cohesion_policy.pdf

European Commission (2018), A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, Press Release, Brussels

Heinrich Boll Stiftung (2015). Greek Lignite reserves and characteristics, Retrieved from: https://gr.boell.org/en/2015/12/16/greek-lignite-reserves-and-characteristics

Hellenic Ministry of Environment, Energy & Climate Change, "Energy "(2018), Retrieved from: http://www.ypeka.gr/Default.aspx?tabid=225&language=el-GR

Hellenic Ministry of Environment, Energy & Climate Change, (2018). 7th National Communication and 3rd Biennial Report under the United Nations Framework Convention on Climate Change, Retrieved from: http://unfccc.int/files/national_reports/annex_i_natcom_/application/pdf/48032915_greece-nc7-br3-1-nc7_greece.pdf

Hellenic Ministry of Environment, Energy & Climate Change, (2014). National Energy Efficiency Action Plan, Pursuant to article 24(2) of Directive 2012/27/EU Centre for Renewable Energy Sources, Retrieved from: https://ec.europa.eu/energy/sites/ener/files/documents/EL_NEEAP_en%20version.pdf

Hellenic Ministry of Environment, Energy & Climate Change, (2010). National Renewable Energy Action Plan in the scope of Directive 2009/28/EC, Retrieved from: http://www.ypeka.gr/LinkClick.aspx?fileticket=CEYdUkQ719k%3D

Intergovernmental Panel on Climate Change, (2014). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Retrieved from: https://www.ipcc.ch/report/ar5/wg3/

International Renewable Energy Agency, (2018). Year in review 2018, Retrieved from: https://www.irena.org/newsroom/articles/2018/Dec/IRENA-Year-in-Review-2018

International Energy Agency, Energy Policies of IEA Countries, Greece 2017 Review, Retrieved from:

https://www.iea.org/publications/freepublications/publication/EnergyPoliciesofIEACountriesGreeceReview2017.pdf

LAGIE (2014). Special RES & CHP Account Monthly Bulletin, Retrieved from: http://www.lagie.gr/fileadmin/groups/EDSHE/MiniaiaDeltiaEL/2014_01_Miniaio_Deltio_EL_APESITHYA_v2.pdf

National Center for the Environment and Sustainable Development (NCESD) Summary 2018, Retrieved from: http://ekpaa.ypeka.gr/images/Greece%20State%20of%20the%20Environment%20Report%20Summary%202018%20English%20Version_WEB.pdf

Norton Rose Fulbright (2016). Law 4414/2016: A new support scheme for renewable electricity in Greece, Briefing October 2016, Retrieved from: http://www.nortonrosefulbright.com/files/law-44142016-a-new-support-scheme-for-renewable-electricity-in-greece-143582.pdf

OECD (2005). Cost-benefit analysis and the environment: Further developments and policy use, June 25, Retrieved from: http://www.oecd.org/environment/tools-evaluation/cost-benefit-analysis-and-the-environment-9789264085169-en.htm

Public Power Corporation Renewables, Retrieved from: https://www.ppcr.gr/en/solar-power

The Conversation, Does “green energy” have hidden health and environmental costs?, Retrieved from: https://theconversation.com/does-green-energy-have-hidden-health-and-environmental-costs-52484

United Nations Environment Programme. (2012): Business and Climate Change Adaptation: Toward Resilient Companies and Communities, UN Global Compact and UN Environment Programme

United Nations (1998). Kyoto Protocol to the United Nations Framework Convention on Climate Change, Retrieved from: https://unfccc.int/resource/docs/convkp/kpeng.pdf

United States Environmental Protection Agency, Global Greenhouse Gas Emission Data, Retrieved from: https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

United States Energy Information Administration (2017). Annual Energy Outlook

Appendix

Table 1: Lignite base scenario – Discount rate 3%

YEAR	ALLOCATED COSTS	CONSTUCTION COSTS	MAINTENANCE & OPERATING COSTS	CO_2 COSTS	MINING COSTS	RESTORING COSTS	TOTAL COSTS	TOTAL BENEFITS
1	138863413,8	134.818.848,33	0	0	0	0	134.818.848,33	0
2	208295120,7	196.338.128,64	0	0	0	0	196.338.128,64	0
3	555453655,1	508.318.779,65	25415938,98	0	0	0	533.734.718,63	0
4	416590241,3	370.135.033,72	24675668,91	0	0	0	394.810.702,64	0
5	69431706,89	59.892.400,28	23956960,11	0	0	0	83.849.360,39	0
6		0	23259184,57	117747,8578	41521631,96	0	64.898.564,39	196984672
7		0	22581732,60	114318,3085	40312264,04	0	63.008.314,95	191247254,4
8		0	21924012,23	110988,6491	39138120,43	0	61.173.121,31	185676946
9		0	21285448,77	107755,97	37998175,17	0	59.391.379,91	180268879,6
10		0	20665484,24	104617,4466	36891432,21	1264959,655	58.926.493,55	175018329,7
11		0	20063576,93	101570,3365	35816924,47	0	55.982.071,74	169920708,5
12		0	19479200,90	98611,97715	34773713,08	0	54.351.525,96	164971561,6
13		0	18911845,54	95739,78364	33760886,49	0	52.768.471,81	160166564,7
14		0	18361015,09	92951,24626	32777559,69	0	51.231.526,03	155501519,1
15		0	17826228,24	90243,9284	31822873,49	1091165,311	50.830.510,97	150972348,6
16		0	17307017,71	87615,46447	30895993,68	0	48.290.626,85	146575095,8
17		0	16802929,81	85063,55774	29996110,37	0	46.884.103,74	142305918,2
18		0	16313524,09	82585,97839	29122437,25	0	45.518.547,32	138161085,7
19		0	15838372,90	80180,56154	28274210,92	0	44.192.764,39	134136976,4
20		0	15377061,07	77845,20538	27450690,22	941248,7821	43.846.845,28	130230074,1
21		0	14929185,51	75577,8693	26651155,55	0	41.655.918,93	126436965,2
22		0	14494354,86	73376,57214	25874908,3	0	40.442.639,73	122754335,1
23		0	14072189,18	71239,39042	25121270,2	0	39.264.698,77	119178966,1
24		0	13662319,60	69164,45672	24389582,71	0	38.121.066,77	115707734,1
25		0	13264387,96	67149,95798	23679206,52	811929,4677	37.822.673,90	112337605,9
26		0	12878046,56	65194,13396	22989520,89	0	35.932.761,59	109065636,8
27		0	12502957,83	63295,27569	22319923,2	0	34.886.176,30	105888967,8
28		0	12138794,01	61451,72397	21669828,35	0	33.870.074,08	102804823,1
29		0	11785236,90	59661,86794	21038668,3	0	32.883.567,06	99810507,88
30		0	11441977,57	57924,14363	20425891,55	700377,4912	32.626.170,76	96903405,71
31		0	11108716,09	56237,03265	19830962,67	0	30.995.915,79	94080976,41
32		0	10785161,25	54599,06082	19253361,82	0	30.093.122,13	91340753,8
33		0	10471030,34	53008,79691	18692584,29	0	29.216.623,43	88680343,49
34		0	10166048,88	51464,85137	18148140,08	0	28.365.653,81	86097420,87
35		0	9869950,36	49965,87512	17619553,48	604151,7763	28.143.621,50	83589729
36		0	9582476,08	48510,55837	17106362,6	0	26.737.349,24	81155076,7
37		0	9303374,84	47097,62948	16608119,03	0	25.958.591,50	78791336,6
38		0	9032402,75	45725,85387	16124387,41	0	25.202.516,02	76496443,3
39		0	8769323,06	44394,03288	15654745,06	0	24.468.462,15	74268391,55
40		0	8513905,89	43101,0028	15198781,61	521146,6293	24.276.935,13	72105234,52
TOTAL		1.269.503.190,62	588817042,2	2.605.976,36	918949977,1	5934979,113	2.785.811.165,37	**4359632589**
							NPV (BASE)	**1.573.821.423,18**
							B/C (BASE)	**1,564941889**
INITIAL INVESTMENT	1.388.634.137,82							
R=	3%							
PRICE	54,7							
MINE COST	11,53							
MWH	4300000							
RESTORING COST	1.700.000							
CO2 COST	**140597,1**							
PRICE CO2	31,14							

Table 2: Lignite base scenario – Discount rate 7%

YEAR	ALLOCATED COSTS	CONSTUCTION COSTS	MAINTENANCE & OPERATING COSTS	CO_2 COSTS	MINING COSTS	RESTORING COSTS	TOTAL COSTS	TOTAL BENEFITS
1	138863413,8	129.778.891,39	0	0	0	0	129.778.891,39	0
2	208295120,7	181.933.025,31	0	0	0	0	181.933.025,31	0
3	555453655,1	453.415.639,39	22670781,97	0	0	0	476.086.421,36	0
4	416590241,3	317.814.700,51	21187646,70	0	0	0	339.002.347,21	0
5	69431706,89	49.503.847,43	19801538,97	0	0	0	69.305.386,40	0
6		0	18506111,19	46842,89214	33036581,11	0	51.589.535,20	125384283,6
7		0	17295431,02	43778,40387	30875309,45	0	48.214.518,87	117181573,4
8		0	16163954,22	40914,39614	28855429,4	0	45.060.298,01	109515489,2
9		0	15106499,27	38237,7534	26967691,02	0	42.112.428,05	102350924,5
10		0	14118223,62	35736,21813	25203449,55	864193,7966	40.221.603,19	95655069,6
11		0	13194601,51	33398,3347	23554625,75	0	36.782.625,60	89397261,31
12		0	12331403,28	31213,39692	22013668,93	0	34.376.285,61	83548842,35
13		0	11524675,97	29171,39899	20573522,36	0	32.127.369,73	78083030,23
14		0	10770725,20	27262,98971	19227590,99	0	30.025.579,18	72974794,61
15		0	10066098,32	25479,42963	17969711,21	616158,2334	28.677.447,19	68200742,62
16		0	9407568,52	23812,55106	16794122,62	0	26.225.503,70	63739011,8
17		0	8792120,12	22254,72062	15695441,7	0	24.509.816,54	59569169,9
18		0	8216934,69	20798,80431	14668637,11	0	22.906.370,60	55672121,41
19		0	7679378,21	19438,13487	13709006,64	0	21.407.822,99	52030020,01
20		0	7176988,98	18166,48119	12812155,74	439312,3048	20.446.623,51	48626186,92
21		0	6707466,34	16978,0198	11973977,33	0	18.698.421,69	45445034,51
22		0	6268660,13	15867,30823	11190633,02	0	17.475.160,46	42471994,87
23		0	5858560,87	14829,26003	10458535,53	0	16.331.925,66	39693453,15
24		0	5475290,53	13859,12152	9774332,27	0	15.263.481,92	37096685,18
25		0	5117093,96	12952,45002	9134889,972	313223,6018	14.578.159,98	34669799,24
26		0	4782330,80	12105,09348	8537280,348	0	13.331.716,24	32401681,53
27		0	4469468,04	11313,17147	7978766,68	0	12.459.547,89	30281945,35
28		0	4177072,93	10573,05745	7456791,29	0	11.644.437,28	28300883,51
29		0	3903806,48	9881,362103	6968963,823	0	10.882.651,66	26449423,84
30		0	3648417,27	9234,917854	6513050,301	223324,0992	10.394.026,59	24719087,7
31		0	3409735,77	8630,764349	6086962,899	0	9.505.329,43	23101951,12
32		0	3186668,94	8066,134906	5688750,372	0	8.883.485,45	21590608,53
33		0	2978195,27	7538,443837	5316589,133	0	8.302.322,85	20178138,81
34		0	2783360,07	7045,274614	4968774,891	0	7.759.180,23	18858073,65
35		0	2601271,09	6584,368798	4643714,851	159226,9962	7.410.797,31	17624367,9
36		0	2431094,48	6153,615699	4339920,422	0	6.777.168,51	16471371,87
37		0	2272050,91	5751,04271	4056000,394	0	6.333.802,35	15393805,49
38		0	2123412,07	5374,806271	3790654,574	0	5.919.441,45	14386734,1
39		0	1984497,26	5023,183431	3542667,826	0	5.532.188,27	13445545,89
40		0	1854670,34	4694,563954	3310904,51	113526,6477	5.283.796,06	12565930,73
TOTAL		1.132.446.104,02	320043805,3	648.961,87	457689104	2728965,68	1.913.556.940,90	**1737075038**
							NPV (WORSE)	**-176.481.902,53**
							B/C (WORSE)	**0,90777285**
AL INVESTI	1.388.634.137,82							
R=	7%							
PRICE	43,76							
MINE COS	11,53							
MWH	4300000							
RESTORI NG COST	1.700.000							
CO2 COST	**70298,55**							
PRICE CO2	15,57							

Table 3: Lignite best scenario – Discount rate 3%

YEAR	ALLOCATED COSTS	CONSTUCTION COSTS	MAINTENANCE & OPERATING COSTS	CO_2 COSTS	MINING COSTS	RESTORING COSTS	TOTAL COSTS	TOTAL BENEFITS
1	138863413,8	134.818.848,33	0	0	0	0	134.818.848,33	0
2	208295120,7	196.338.128,64	0	0	0	0	196.338.128,64	0
3	555453655,1	508.318.779,65	25415938,98	0	0	0	533.734.718,63	0
4	416590241,3	370.135.033,72	24675668,91	0	0	0	394.810.702,64	0
5	69431706,89	59.892.400,28	23956960,11	0	0	0	83.849.360,39	0
6		0	23259184,57	58873,92889	41521631,96	0	64.839.690,47	196984672
7		0	22581732,60	57159,15426	40312264,04	0	62.951.155,79	191247254,4
8		0	21924012,23	55494,32453	39138120,43	0	61.117.626,98	185676946
9		0	21285448,77	53877,98498	37998175,17	0	59.337.501,92	180268879,6
10		0	20665484,24	52308,72328	36891432,21	1264959,655	58.874.184,82	175018329,7
11		0	20063576,93	50785,16823	35816924,47	0	55.931.286,57	169920708,5
12		0	19479200,90	49305,98858	34773713,08	0	54.302.219,97	164971561,6
13		0	18911845,54	47869,89182	33760886,49	0	52.720.601,92	160166564,7
14		0	18361015,09	46475,62313	32777559,69	0	51.185.050,40	155501519,1
15		0	17826228,24	45121,9642	31822873,49	1091165,311	50.785.389,00	150972348,6
16		0	17307017,71	43807,73224	30895993,68	0	48.246.819,12	146575095,8
17		0	16802929,81	42531,77887	29996110,37	0	46.841.571,96	142305918,2
18		0	16313524,09	41292,98919	29122437,25	0	45.477.254,33	138161085,7
19		0	15838372,90	40090,28077	28274210,92	0	44.152.674,11	134136976,4
20		0	15377061,07	38922,60269	27450690,22	941248,7821	43.807.922,67	130230074,1
21		0	14929185,51	37788,93465	26651155,55	0	41.618.129,99	126436965,2
22		0	14494354,86	36688,28607	25874908,3	0	40.405.951,45	122754335,1
23		0	14072189,18	35619,69521	25121270,2	0	39.229.079,08	119178966,1
24		0	13662319,60	34582,22836	24389582,71	0	38.086.484,54	115707734,1
25		0	13264387,96	33574,97899	23679206,52	811929,4677	37.789.098,92	112337605,9
26		0	12878046,56	32597,06698	22989520,89	0	35.900.164,52	109065636,8
27		0	12502957,83	31647,63785	22319923,2	0	34.854.528,66	105888967,8
28		0	12138794,01	30725,86199	21669828,35	0	33.839.348,21	102804823,1
29		0	11785236,90	29830,93397	21038668,3	0	32.853.736,13	99810507,88
30		0	11441977,57	28962,07181	20425891,55	700377,4912	32.597.208,68	96903405,71
31		0	11108716,09	28118,51632	19830962,67	0	30.967.797,28	94080976,41
32		0	10785161,25	27299,53041	19253361,82	0	30.065.822,60	91340753,8
33		0	10471030,34	26504,39846	18692584,29	0	29.190.119,03	88680343,49
34		0	10166048,88	25732,42569	18148140,08	0	28.339.921,39	86097420,87
35		0	9869950,36	24982,93756	17619553,48	604151,7763	28.118.638,56	83589729
36		0	9582476,08	24255,27918	17106362,6	0	26.713.093,96	81155076,7
37		0	9303374,84	23548,81474	16608119,03	0	25.935.042,68	78791336,6
38		0	9032402,75	22862,92693	16124387,41	0	25.179.653,09	76496443,3
39		0	8769323,06	22197,01644	15654745,06	0	24.446.265,14	74268391,55
40		0	8513905,89	21550,5014	15198781,61	521146,6293	24.255.384,63	72105234,52
TOTAL		1.269.503.190,62	588817042,2	1.302.988,18	918949977,1	5934979,113	2.784.508.177,20	**4359632589**
							NPV (BEST)	**1.575.124.411,36**
							B/C (BEST)	**1,565674191**
IAL INVESTM	1.388.634.137,82							
R=	3%							
PRICE	54,7							
MINE COST	11,53							
MWH	4300000							
RESTORING COST	1.700.000							
CO2 COSTS	**70298,55**							
PRICE CO2	15,57							

Table 4: Wind base scenario – Discount rate 3%

YEAR	CONSTUCTION COSTS	MAINTENANCE & OPERATING COSTS	REPLACEMENT COSTS	TOTAL COSTS	TOTAL BENEFITS
1	839.417.475,73	30116504,85	0,00	869.533.980,58	80641299,03
2	0	29239325,10	0,00	29.239.325,10	78292523,33
3	0	28387694,27	0,00	28.387.694,27	76012158,57
4	0	27560868,23	0,00	27.560.868,23	73798212,21
5	0	26758124,49	0,00	26.758.124,49	71648749,71
6	0	25978761,64	0,00	25.978.761,64	69561892,93
7	0	25222098,68	0,00	25.222.098,68	67535818,38
8	0	24487474,45	0,00	24.487.474,45	65568755,7
9	0	23774247,04	0,00	23.774.247,04	63658986,12
10	0	23081793,24	0,00	23.081.793,24	61804840,89
11	0	22409508,00	0,00	22.409.508,00	60004699,9
12	0	21756803,88	0,00	21.756.803,88	58256990,19
13	0	21123110,57	0,00	21.123.110,57	56560184,65
14	0	20507874,34	0,00	20.507.874,34	54912800,63
15	0	19910557,61	0,00	19.910.557,61	53313398,67
16	0	19330638,45	0,00	19.330.638,45	51760581,24
17	0	18767610,15	0,00	18.767.610,15	50252991,49
18	0	18220980,73	0,00	18.220.980,73	48789312,13
19	0	17690272,55	0,00	17.690.272,55	47368264,2
20	0	17175021,89	0,00	17.175.021,89	45988606,02
21	0	16674778,54	0,00	16.674.778,54	44649132,06
22	0	16189105,38	0,00	16.189.105,38	43348671,9
23	0	15717578,04	0,00	15.717.578,04	42086089,22
24	0	15259784,50	0,00	15.259.784,50	40860280,8
25	0	14815324,76	0,00	14.815.324,76	39670175,53
26	0	14383810,45	80182092,27	94.565.902,71	38514733,53
27	0	13964864,51	0,00	13.964.864,51	37392945,17
28	0	13558120,88	0,00	13.558.120,88	36303830,27
29	0	13163224,16	0,00	13.163.224,16	35246437,15
30	0	12779829,28	0,00	12.779.829,28	34219841,89
31	0	12407601,24	0,00	12.407.601,24	33223147,47
32	0	12046214,80	0,00	12.046.214,80	32255482,98
33	0	11695354,17	0,00	11.695.354,17	31316002,89
34	0	11354712,79	0,00	11.354.712,79	30403886,3
35	0	11023993,00	0,00	11.023.993,00	29518336,22
36	0	10702905,83	0,00	10.702.905,83	28658578,85
37	0	10391170,70	0,00	10.391.170,70	27823862,96
38	0	10088515,25	0,00	10.088.515,25	27013459,19
39	0	9794675,00	0,00	9.794.675,00	26226659,41
40	0	9509393,20	0,00	9.509.393,20	25462776,12
TOTAL	839.417.475,73	717020226,64		1.636.619.794,64	**1919925396**
				NPV (BASE)	**283.305.601,29**
				B/C (BASE)	**1,173104103**
INITIAL IN	864.600.000,00				
R=	3%				
PRICE	69,53				
MWH	1194600				
M&O COST	47			25 YEAR LIFETIME	
MW	660			BENEFITS	1446345416
				COSTS	1.379.573.317,11
				NPV	66.772.098,40
				B/C	1,048400544

Table 5: Wind worst scenario – Discount rate 7%

YEAR	CONSTUCTION COST	MAINTENANCE & OPERATING COSTS	REPLACEMENT COSTS	TOTAL COSTS	TOTAL BENEFITS
1	808.037.383,18	28990654,21	0,00	837.028.037,38	77626671,03
2	0	27094069,35	0,00	27.094.069,35	72548290,68
3	0	25321560,14	0,00	25.321.560,14	67802140,82
4	0	23665009,48	0,00	23.665.009,48	63366486,75
5	0	22116831,29	0,00	22.116.831,29	59221015,65
6	0	20669935,78	0,00	20.669.935,78	55346743,6
7	0	19317696,99	0,00	19.317.696,99	51725928,6
8	0	18053922,42	0,00	18.053.922,42	48341989,35
9	0	16872824,69	0,00	16.872.824,69	45179429,3
10	0	15768995,04	0,00	15.768.995,04	42223765,7
11	0	14737378,54	0,00	14.737.378,54	39461463,27
12	0	13773250,98	0,00	13.773.250,98	36879872,21
13	0	12872197,17	0,00	12.872.197,17	34467170,29
14	0	12030090,82	0,00	12.030.090,82	32212308,68
15	0	11243075,53	0,00	11.243.075,53	30104961,39
16	0	10507547,22	0,00	10.507.547,22	28135477,93
17	0	9820137,59	0,00	9.820.137,59	26294839,19
18	0	9177698,68	0,00	9.177.698,68	24574616,06
19	0	8577288,49	0,00	8.577.288,49	22966930,9
20	0	8016157,47	0,00	8.016.157,47	21464421,4
21	0	7491735,95	0,00	7.491.735,95	20060206,92
22	0	7001622,38	0,00	7.001.622,38	18747856,93
23	0	6543572,32	0,00	6.543.572,32	17521361,62
24	0	6115488,15	0,00	6.115.488,15	16375104,32
25	0	5715409,49	0,00	5.715.409,49	15303835,81
26	0	5341504,19	29776044,65	35.117.548,84	14302650,29
27	0	4992059,99	0,00	4.992.059,99	13366962,89
28	0	4665476,63	0,00	4.665.476,63	12492488,68
29	0	4360258,53	0,00	4.360.258,53	11675223,07
30	0	4075007,97	0,00	4.075.007,97	10911423,43
31	0	3808418,67	0,00	3.808.418,67	10197591,99
32	0	3559269,78	0,00	3.559.269,78	9530459,801
33	0	3326420,36	0,00	3.326.420,36	8906971,777
34	0	3108804,07	0,00	3.108.804,07	8324272,689
35	0	2905424,37	0,00	2.905.424,37	7779694,101
36	0	2715349,88	0,00	2.715.349,88	7270742,151
37	0	2537710,16	0,00	2.537.710,16	6795086,122
38	0	2371691,74	0,00	2.371.691,74	6350547,778
39	0	2216534,34	0,00	2.216.534,34	5935091,381
40	0	2071527,42	0,00	2.071.527,42	5546814,375
TOTAL	808.037.383,18	413549608,30		1.251.363.036,13	**1107338909**
				NPV (WORST)	**-144.024.127,20**
				B/C (WORST)	**0,8849062**
INITIAL INVESTI	864.600.000,00				
R=	7%				
PRICE	69,53				
MWH	1194600				
M&O COSTS (/KW)	47			25 YEAR LIFETIME	
MW	660			BENIFITS	967952888,4
				COSTS	1.169.531.533,37
				PNPV	-201.578.644,95
				B/C	0,827641548

Table 6: Wind best scenario – Discount rate 3%

YEAR	CONSTUCTION COST	MAINTENANCE & OPERATING COSTS	REPLACEMENT COSTS	TOTAL COSTS	TOTAL BENEFITS
1	839.417.475,73	30116504,85	0,00	869.533.980,58	88701949,51
2	0	29239325,10	0,00	29.239.325,10	86118397,59
3	0	28387694,27	0,00	28.387.694,27	83610094,74
4	0	27560868,23	0,00	27.560.868,23	81174849,27
5	0	26758124,49	0,00	26.758.124,49	78810533,27
6	0	25978761,64	0,00	25.978.761,64	76515080,84
7	0	25222098,68	0,00	25.222.098,68	74286486,26
8	0	24487474,45	0,00	24.487.474,45	72122802,19
9	0	23774247,04	0,00	23.774.247,04	70022138,05
10	0	23081793,24	0,00	23.081.793,24	67982658,3
11	0	22409508,00	0,00	22.409.508,00	66002580,87
12	0	21756803,88	0,00	21.756.803,88	64080175,61
13	0	21123110,57	0,00	21.123.110,57	62213762,72
14	0	20507874,34	0,00	20.507.874,34	60401711,38
15	0	19910557,61	0,00	19.910.557,61	58642438,23
16	0	19330638,45	0,00	19.330.638,45	56934406,05
17	0	18767610,15	0,00	18.767.610,15	55276122,38
18	0	18220980,73	0,00	18.220.980,73	53666138,23
19	0	17690272,55	0,00	17.690.272,55	52103046,83
20	0	17175021,89	0,00	17.175.021,89	50585482,36
21	0	16674778,54	0,00	16.674.778,54	49112118,8
22	0	16189105,38	0,00	16.189.105,38	47681668,73
23	0	15717578,04	0,00	15.717.578,04	46292882,27
24	0	15259784,50	0,00	15.259.784,50	44944545,89
25	0	14815324,76	0,00	14.815.324,76	43635481,45
26	0	14383810,45	80182092,27	94.565.902,71	42364545,09
27	0	13964864,51	0,00	13.964.864,51	41130626,3
28	0	13558120,88	0,00	13.558.120,88	39932646,9
29	0	13163224,16	0,00	13.163.224,16	38769560,09
30	0	12779829,28	0,00	12.779.829,28	37640349,61
31	0	12407601,24	0,00	12.407.601,24	36544028,74
32	0	12046214,80	0,00	12.046.214,80	35479639,56
33	0	11695354,17	0,00	11.695.354,17	34446252
34	0	11354712,79	0,00	11.354.712,79	33442963,1
35	0	11023993,00	0,00	11.023.993,00	32468896,22
36	0	10702905,83	0,00	10.702.905,83	31523200,21
37	0	10391170,70	0,00	10.391.170,70	30605048,75
38	0	10088515,25	0,00	10.088.515,25	29713639,56
39	0	9794675,00	0,00	9.794.675,00	28848193,75
40	0	9509393,20	0,00	9.509.393,20	28007955,1
TOTAL	839.417.475,73	717020226,64		1.636.619.794,64	**2111835097**
				NPV (BEST)	**475.215.302,16**
				B/C (BEST)	**1,290363897**
INITIAL INVESTM	864.600.000,00				
R=	3%				
PRICE	76,48				
MWH	1194600				
M&O COSTS (/KW)	47			25 YEAR LIFETIME	
MW	660			BENEFITS	1590917552
				COSTS	1.379.573.317,11
				NPV	211.344.234,71
				B/C	1,153195363

Table 7: Solar base scenario – Discount rate 3%

YEAR	CONSTUCTION COSTS	MAINTENANCE & OPERATING COSTS	REPLACEMENT COSTS	TOTAL COSTS	TOTAL BENEFITS
1	1.121.359.223,30	28194174,76	0,00	1.149.553.398,06	60514182,52
2	0	27372985,20	0,00	27.372.985,20	58751633,52
3	0	26575713,79	0,00	26.575.713,79	57040420,89
4	0	25801663,87	0,00	25.801.663,87	55379049,41
5	0	25050159,10	0,00	25.050.159,10	53766067,39
6	0	24320542,81	0,00	24.320.542,81	52200065,43
7	0	23612177,49	0,00	23.612.177,49	50679675,17
8	0	22924444,16	0,00	22.924.444,16	49203568,13
9	0	22256741,91	0,00	22.256.741,91	47770454,49
10	0	21608487,29	0,00	21.608.487,29	46379082,03
11	0	20979113,87	0,00	20.979.113,87	45028234,98
12	0	20368071,72	0,00	20.368.071,72	43716732,99
13	0	19774826,91	0,00	19.774.826,91	42443430,09
14	0	19198861,08	0,00	19.198.861,08	41207213,68
15	0	18639670,95	0,00	18.639.670,95	40007003,57
16	0	18096767,91	0,00	18.096.767,91	38841751,04
17	0	17569677,59	0,00	17.569.677,59	37710437,9
18	0	17057939,41	0,00	17.057.939,41	36612075,63
19	0	16561106,22	0,00	16.561.106,22	35545704,5
20	0	16078743,90	0,00	16.078.743,90	34510392,72
21	0	15610430,97	0,00	15.610.430,97	33505235,65
22	0	15155758,23	0,00	15.155.758,23	32529355
23	0	14714328,37	0,00	14.714.328,37	31581898,06
24	0	14285755,70	0,00	14.285.755,70	30662036,95
25	0	13869665,73	0,00	13.869.665,73	29768967,91
26	0	13465694,88	107113482,04	120.579.176,92	28901910,59
27	0	13073490,18	0,00	13.073.490,18	28060107,37
28	0	12692708,91	0,00	12.692.708,91	27242822,69
29	0	12323018,36	0,00	12.323.018,36	26449342,42
30	0	11964095,50	0,00	11.964.095,50	25678973,22
31	0	11615626,70	0,00	11.615.626,70	24931041,96
32	0	11277307,47	0,00	11.277.307,47	24204895,11
33	0	10948842,21	0,00	10.948.842,21	23499898,16
34	0	10629943,89	0,00	10.629.943,89	22815435,11
35	0	10320333,87	0,00	10.320.333,87	22150907,88
36	0	10019741,62	0,00	10.019.741,62	21505735,8
37	0	9727904,49	0,00	9.727.904,49	20879355,15
38	0	9444567,47	0,00	9.444.567,47	20271218,59
39	0	9169482,98	0,00	9.169.482,98	19680794,75
40	0	8902410,66	0,00	8.902.410,66	19107567,72
TOTAL	1.121.359.223,30	671252978,13		1.899.725.683,47	**1440734676**
				NPV (BASE)	**-458.991.007,31**
				B/C (BASE)	**0,758390903**
INITIAL INVESTM	1.155.000.000,00				
R=	3%				
PRICE	63,81				
MWH	976800				
M&O COSTS (/KW)	44			25 YEAR LIFETIME	
MW	660			BENEFITS	1085354670
				COSTS	1.627.037.032,26
				NPV	-541.682.362,61
				B/C	0,667074349

Table 8: Solar best scenario – Discount rate 3%

YEAR	CONSTUCTION COSTS	MAINTENANCE & OPERATING COSTS	REPLACEMENT COSTS	TOTAL COSTS	TOTAL BENEFITS
1	1.121.359.223,30	22555339,81	0,00	1.143.914.563,11	75640357,28
2	0	21898388,16	0,00	21.898.388,16	73437240,08
3	0	21260571,03	0,00	21.260.571,03	71298291,34
4	0	20641331,10	0,00	20.641.331,10	69221642,08
5	0	20040127,28	0,00	20.040.127,28	67205477,74
6	0	19456434,25	0,00	19.456.434,25	65248036,65
7	0	18889741,99	0,00	18.889.741,99	63347608,39
8	0	18339555,33	0,00	18.339.555,33	61502532,42
9	0	17805393,53	0,00	17.805.393,53	59711196,52
10	0	17286789,83	0,00	17.286.789,83	57972035,46
11	0	16783291,10	0,00	16.783.291,10	56283529,57
12	0	16294457,38	0,00	16.294.457,38	54644203,47
13	0	15819861,53	0,00	15.819.861,53	53052624,73
14	0	15359088,86	0,00	15.359.088,86	51507402,65
15	0	14911736,76	0,00	14.911.736,76	50007187,04
16	0	14477414,33	0,00	14.477.414,33	48550667,03
17	0	14055742,07	0,00	14.055.742,07	47136569,93
18	0	13646351,52	0,00	13.646.351,52	45763660,12
19	0	13248884,97	0,00	13.248.884,97	44430737,99
20	0	12862995,12	0,00	12.862.995,12	43136638,82
21	0	12488344,78	0,00	12.488.344,78	41880231,86
22	0	12124606,58	0,00	12.124.606,58	40660419,29
23	0	11771462,70	0,00	11.771.462,70	39476135,23
24	0	11428604,56	0,00	11.428.604,56	38326344,88
25	0	11095732,59	0,00	11.095.732,59	37210043,58
26	0	10772555,91	107113482,04	117.886.037,95	36126255,9
27	0	10458792,14	0,00	10.458.792,14	35074034,85
28	0	10154167,13	0,00	10.154.167,13	34052461,02
29	0	9858414,69	0,00	9.858.414,69	33060641,77
30	0	9571276,40	0,00	9.571.276,40	32097710,46
31	0	9292501,36	0,00	9.292.501,36	31162825,69
32	0	9021845,98	0,00	9.021.845,98	30255170,57
33	0	8759073,76	0,00	8.759.073,76	29373952,01
34	0	8503955,11	0,00	8.503.955,11	28518400,01
35	0	8256267,10	0,00	8.256.267,10	27687767
36	0	8015793,30	0,00	8.015.793,30	26881327,18
37	0	7782323,59	0,00	7.782.323,59	26098375,91
38	0	7555653,97	0,00	7.555.653,97	25338229,03
39	0	7335586,38	0,00	7.335.586,38	24600222,36
40	0	7121928,52	0,00	7.121.928,52	23883711,03
TOTAL	1.121.359.223,30	537002382,50		1.765.475.087,84	**1800861899**
				NPV (BASE)	**35.386.811,08**
				B/C (BASE)	**1,02004379**
INITIAL INVESTM	1.155.000.000,00				
R=	3%				
PRICE	79,76				
MWH	976800				
M&O COSTS (/KW)	35,2			25 YEAR LIFETIME	
MW	660			BENEFITS	1356650814
				COSTS	1.525.901.470,46
				NPV	-169.250.656,32
				B/C	0,88908153