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MSc Thesis Report

Transition of Solar Energy in Greece: A Social Cost Benefit Analysis

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Transition of Solar Energy in Greece:

A Social Cost Benefit Analysis

By

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Cover Picture: Partial view of a typical large-scale PV installation.

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TU Delft

Abstract

In the last years, the country of Greece is striving to overcome the severe financial consequences of the European debt crisis, that hindered its economic growth and downgraded the quality of life of its citizens. The difficult economic state of Greece as well as the long-existing global problem of energy resources depletion constitute the two fundamental concerns, which triggered the conduction of this graduation report.

The impending shortage of fossil fuels coupled with the ever increasing demand for energy consumption led to the rapid development of renewable energy sources (RES), which is evident nowadays. But although RES are the answer to environmental sustainability, their contribution to the overall energy utilization for various countries is still minor. In an effort to support the deployment of renewable technologies, many nations, including Greece, have enforced national and international agreements binding them on their renewable energy targets over the years.

With a rich renewable energy potential, Greece has set its RES goals up to the year 2020, internationally via the Renewable Energy Directive 2009/28/EC and nationally via the National Renewable Energy Action Plan (NREAP), which were both realized in 2009, just before the burst of the economic turmoil. In the years following the crisis and despite all economic adversities troubling Greece, the only RES that continued its fast development and even reached occasionally the committed targets of 2020 was the solar photovoltaic (PV) energy.

Consequently, the thesis focuses on investigating the financial and socio-economic impact of a potential solar PV transition in Greece by addressing the following main research question: how could the fulfillment of the national RES target for solar PV energy by 2020 contribute to the improvement of the Greek people's welfare during the period of the crisis. In this context, the report studies and evaluates the implementation of large-scale solar PV power plants in Greece with respect to the country's national and European energy commitments by 2020, through the conduction of a Social Cost Benefit Analysis (SCBA). The aforementioned analysis is executed in two distinctive parts, depending on the perspective of the people with standing for each part: the financial part considering only private investors' costs and benefits, and the socio-economic part taking into account the whole society. Based on the positive outcome of both parts, the analysis concludes that undertaking the proposed venture would benefit not only private investors but also the Greek society as a whole, assisting at the same time in overcoming the economic recession.

Concluding, it is worth highlighting the apparent scientific value of this graduation report. Despite the limited relevant literature available on the subject and the restrains of the SCBA methodology itself, the current thesis constitutes the first complete SCBA attempt to evaluate an actual national solar energy target according to the European Commission's guidelines and under the unfavorable socio-economic conditions of an economic crisis. In the last part of the report, all barriers that occurred in the course of this work are discussed in detail and specific suggestions for the enhancement of future research along with relevant policy recommendations are given. Finally, reflections on the research performed, related to its strong points, its difficulties and its novelties are presented.

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A very special thanks to my fellow SET-student, Ioanna Barouni, for her precious input to this research. In the context of our initial collaboration, we prepared chapters 2, 3 and 5 jointly. However, personal reasons didn't allow me to keep the same pace with her. Thus, I am responsible for the aforementioned chapters' final content and editing. I am wishing her good luck in her professional and personal life.

Last but not least, I would like to express my very profound gratitude to my parents, sister and Alex for providing me with their unconditional love, unfailing support and continuous encouragement throughout all the years of my studies. You are all very special to me, thank you for always being "there".

Table of Contents

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List of figures

List of tables

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Chapter 1: Introduction

Since its initial outbreak at the end of 2009, the European sovereign debt crisis has influenced adversely the economic welfare of many Member States of the European Union. Greece is, undoubtedly, one of the most severely affected ones, suffering from the crisis's consequences up to this day. Unfortunately, the country's energy sector could not be an exception. In fact, the difficult financial situation Greece got into sharpened even more the chronic inefficiencies of the aforementioned field.

In general, Greece's energy sector is characterized by the presence of limited indigenous resources. In particular, electricity generation depends mainly on solid fuels, with lignite being the cheapest domestic source. Crude oil and natural gas are also commonly used, with the necessary-for-consumption quantities being totally imported from other countries, namely Russia, Libya, Iran, Saudi Arabia, Kazakhstan, Iraq, Algeria and Turkey. On the contrary, the contribution of renewable energy sources (RES) to the total energy production of the country is still quite small, according to the most recent official energy data recorded in 2010. Among RES, biomass and hydropower can be considered as the most prevalent sources, while wind, solar and geothermal power together have an even lower share.

Having set the general context of the economic crisis and the present status of the Greek energy sector, this chapter attempts to familiarize the Reader with the overall purpose of this graduation report. In the following sub-chapters, a short presentation of the case-study analyzed, the evaluation methodology followed and the final results obtained are discussed. Following up next, the key research questions of the thesis are introduced. Furthermore, the scientific and societal relevance of the research is justified. The section concludes with a brief outline of the thesis's structure, useful for the Reader to navigate throughout the report's basic contents.

1.1 Methodology

Over the years, the gap between the increasing energy demands of the world and the diminishing availability of conventional energy reserves grows larger and larger. Without a doubt, the crucial role that renewable energy can play in the transition towards a more competitive, secure and sustainable energy scene has become obvious. Hence, more and more nations are supporting the deployment of renewable energy sources (RES) by committing to the realization of ambitious national and international RES targets throughout the years.

For the case of Europe, the adoption of the Renewable Energy Directive 2009/28/EC in 2009 was an important step towards this direction. The specific targets set by the aforementioned Directive required the European Union (EU) to be able to cover at least 20% of its total energy needs and 10% of its transport needs with the help of renewables by 2020. The allocation of these targets among the EU entity would be defined through the National Renewable Energy Action Plans (NREAPs) submitted by each Member State. Therein a detailed strategy of how the individual national target is aimed to be achieved had to be presented, with regards to electricity, heating, cooling and transport [1].

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. Comparing the initial RES targets to the progress made so far, it can be observed that the unfavorable economic environment of the crisis didn't prevent solar photovoltaic (PV) energy from developing and, under circumstances, even reaching NREAP's commitments. Given the growth of this specific renewable technology, the present thesis aims to investigate the financial and socio-economic impact of a potential solar PV transition in Greece by addressing the following primary research question:

"Could the fulfillment of the national RES target for solar PV energy by 2020 contribute to the improvement of the Greek people's welfare during the period of the crisis?"

To do so, our research focuses on the following case-study, which constitutes the so-called "Project": the implementation of large-scale solar PV power plants in Greece with respect to the country's national and European energy commitments by 2020. The overall value of the Project is assessed through the conduction of a Social Cost Benefit Analysis (SCBA). SCBA is a policy assessment method that quantifies in monetary terms the value of all benefits and costs of a policy or project to all members of society. In our case, the analysis is performed in two distinctive parts, depending on who has standing each time: the financial part concerning only private investors, and the socio-economic part including the whole Greek population. Based on the positive outcome of both parts, the analysis points out that the realization of the proposed Project would benefit not only private investors but also the Greek society as a whole, giving a significant boost to the troubled Greek economy.

1.2 Research Questions

As with any thesis report, a set of basic research questions have to be defined from the start, to guide the investigation process and lead to reliable final conclusions. For the current thesis, the research questions considered are listed below:

- What is the European Sovereign Debt Crisis and how did it influence the economic state of Greece?
- What is the current status of the Greek Energy Sector and how is this sector affected by the economic crisis?
- With regards to Renewable Energy Sources (RES), which are the main national and international targets of Greece and at which extend are they achieved up to this day?
- What is the present status of the Greek Solar PV Sector and what is the impact of the economic crisis on it?
- Which is the case-study under evaluation by the current thesis?
- Which is the methodology chosen for the assessment of the case-study and how is it implemented in our case?
- Which conclusions are drawn by the conduction of the SCBA to the case-study under evaluation?
- Could the fulfillment of the national RES target for Solar PV Energy by 2020 contribute to the improvement of the Greek people's welfare during the period of the crisis?

1.3 Scientific & Societal Relevance

The main objective of this report is to assess whether a large-scale solar PV transition in the crisis-stricken Greece, according to the national RES targets set for 2020, could prove beneficial for the Greek people and improve the unstable economic state of the country. With regards to its novelty, there is no doubt that this thesis constitutes a valuable addition to the existing literature for a number of reasons.

In terms of scientific relevance, the report's contribution is significant, considering the inadequate research conducted on this field so far. Shortly, we could say that the thesis is novel, since, to the best of our knowledge, it is the first scientific document to assess an actual national solar energy target in Greece, combining a complete Social Cost Benefit Analysis with the European Commission's Guidelines. Till now, very few similar studies have been performed for Greece by scholars but not in a thorough way; some focus only on the costs and benefits of the private investors while others consider only environmental externalities as social benefits. Additionally, all calculations done for the sake of this research are based on recent financial data, in an effort to reflect the influence of the European debt crisis on the Greek economy.

Except for the scientific, the thesis has a strong societal relevance too, given its social orientation, which is highlighted by the positive results of the corresponding part of the SCBA conducted. To this extend, the present research is innovative, as it collects and evaluates all social externalities of solar PV energy in Greece for the first time. This gives Greek people the potential to understand better the advantages, which will arise from such a venture and eventually help the economy recover. A higher level of awareness could alter the Greek public attitude towards such investments, making it more positive and supportive. As far as policy makers are concerned, benefits coming from the solar PV transition such as the sustainable use of natural resources, the environmental protection, the reduction in energy imports and the creation of new job opportunities could make them change their perspective towards RES investments. Their conscious choice to propose the realization of the energy projects with the largest benefits to society rather than to private investors could make RES projects more competitive against conventional power generation in the future.

1.4 Thesis Outline

This section is intended to provide the Reader with information about the structural outline of the present work for a better navigation throughout the whole report.

Chapter 1 sets the scene by introducing the main purpose of this research. A short presentation of the topic, the applied methodology and the research questions of the thesis takes place. Furthermore, the scientific and societal relevance of the research are discussed. The chapter closes with a brief description of the report's outline.

Chapter 2 presents the European sovereign debt crisis and the current fragile financial state of Greece. All possible reasons leading to this troublous situation for the country as well as all suggested solutions to confine or completely overcome the problem are discussed.

In Chapter 3 the present energy landscape of Greece is described, focusing on Renewable Energy Sources (RES) and especially on Solar Energy. From this analysis it becomes obvious that, although the country uses mainly conventional fuels to cover its energy needs, it is rich in RES potential, which, if utilized, can help significantly in the improvement of the country's economy. In this direction, the rest of the chapter describes the existing legislative, investing and institutional environment for such kind of investments, prevailing in the country during the period of the crisis.

Chapter 4 introduces the Reader to the photovoltaic (PV) technology of large-scale, which is the one concerning the thesis. Since Greece is the country of interest, the chapter includes an analysis of the past, the present and the future state of the Greek large-scale PV sector. In addition, it mentions all licensing procedures and stakeholders involved in such projects.

Following next, chapter 5 focuses on the theoretical introduction of the Social Cost Benefit Analysis (SCBA). After a brief historical note, the chapter describes the main concept and different types of the method as well as its basic steps and important limitations. Moreover, it stresses out that in every SCBA two different perspectives need to be considered: the perspective of the private investor and the perspective of the society as a whole. The last section of the chapter explains the application of SCBA on renewable energy projects and summarizes the costs and benefits of solar energy projects in Greece on a theoretical basis.

Chapter 6 presents the practical application of the SCBA. After defining the specific case-study under evaluation, the final calculations of the SCBA are made in two distinct parts: the financial and the socio-economic part. The former considers the costs and benefits from the private investor's point of view while the latter all social externalities affecting the Greek population as a whole. All costs and benefits are identified, monetized and aggregated and with the help of the discounted cash flow methodology, the Net Present Value (NPV) and the Internal

Rate of Return (IRR) for the financial part as well as the Social Net Present Value (SNPV) and the Social Internal Rate of Return (SIRR) for the socio-economic part are calculated.

Lastly, chapter 7 summarizes our conclusions with regards to the main scope of the thesis. Certain policy recommendations, suggestions for future scientific research as well as general reflections with regards to the strong points, the limitations, the difficulties and the novelties of this work are made.

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Chapter 2: Greece & the European Sovereign Debt Crisis

The much-discussed term “European Sovereign Debt Crisis” refers to the multi-year debt crisis that has been taking place in the European Union since the end of 2009. A number of causes acting simultaneously that period, such as the financial crisis of 2007-2008 and the real estate market crisis, combined with the misguided fiscal policies adopted by several Eurozone Member States, made it impossible for Greece, Portugal, Ireland, Spain and Cyprus to repay their government debt or to bail out their heavily indebted national banks without the assistance of third-party financial institutions. This situation resulted in a crisis of confidence towards European businesses and economies [2], [3], [4].

With Greece being our focus, this chapter presents a concise timeline of the main economic events that occurred in the country during this crucial period along with a description of all European Institutions involved. After identifying the origins of the problem, the chapter concludes by suggesting potential solutions to overcome it and to avoid a further contagion of the rest of the Eurozone members in the future.

2.1 European Institutions

Before moving on to the timeline of the economic crisis, it is necessary to familiarize first with all of the European Union’s institutions involved in the aforementioned situation. In the following section, a short description explaining the main roles and responsibilities of each of them is given.

- **The European Union (EU)**

Founded in 1993, the European Union (EU) is an economic and political partnership between 28 European countries, comprising not only financial matters but also policy areas, such as development aid, human rights, living standards and environmental issues. The EU is the successor of the European Economic Community (EEC), which was created after World War II to foster economic co-operation and to ensure that countries would be able to trade peacefully with each another, avoiding the possibility of a new conflict [5].

- **The Economic and Monetary Union (EMU)**

The formation of the Economic and Monetary Union was realized by the Treaty on European Union (TEU), signed in Maastricht in 1992. Its main purpose is to bring the EU members closer to an economic integration, which ensures the internal robustness of the economy for EU as a whole and for each Member State individually. More specifically, the EMU is responsible for:

- The coordination of economic policy-making between Member States
- The coordination of fiscal policies by setting limits on government debt and deficit
- An independent monetary policy run by the European Central Bank (ECB)
- The single currency and the euro area

At this point, it is important to highlight that all EU countries are part of the EMU but only some of them have taken a step further by replacing their national currencies with a single common currency, the euro [6], [7], [8].

- **The Euro Area or Eurozone**

Except for the formation of EMU, the Treaty on European Union (the Maastricht Treaty) signed in 1992, decided the adoption of a single currency among its members, in an effort to strengthen the European market and create a stable and blooming European economy. This common currency was Euro and it was first launched on 1st January 1999. Currently, the Euro is embraced by 19 Member States, which altogether constitute the Euro Area or Eurozone. These states are Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Spain, and Slovenia. According to the Maastricht Treaty, all EU Member States (except for Denmark, Sweden and the United Kingdom) will eventually adopt the Euro, once they meet all the required preconditions. These preconditions, also known as the 'convergence criteria' (or 'Maastricht criteria') are [8], [9], [10], [11], [12]:

- ***Price stability:*** Inflation rate should not exceed 1.5 percentage points above the rate of the three best performing Member States.
- ***Sound public finances:*** Public deficit should not exceed 3% of GDP.
- ***Sustainable public finances:*** Government debt should not exceed 60% of GDP.
- ***Durability of convergence:*** Long-term interest rate should not exceed 2 percentage points above the rate of the three best performing members in terms of price stability.
- ***Exchange rate stability:*** Participation in the Exchange Rate Mechanism (ERM II) for at least 2 years without severe tensions, to ensure that exchange rate fluctuations between the Euro and other EU currencies do not disrupt economic stability within the single market.

2.2 The Eurozone debt crisis

Since its eruption in 2009, the Eurozone debt crisis has been much debated among politicians, economists, academics and everyday people. Yet, nobody can deny its significant adverse economic and labour market effects, which eventually resulted in a subdued economic growth for the entire European Union. The crisis was triggered by a combination of complex factors, which are presented in the following paragraphs.

To begin with, many countries have repeatedly violated one or more of the 'convergence criteria' of the Maastricht Treaty, in their effort to join the Eurozone and share the single currency. However, the infringement of the rules remained unpunished by the EU's Economic and Financial Affairs Council (ECOFIN). The Council's members often refrained from imposing penalties to such violations, to prevent their own country's punishment in a similar situation. Furthermore, the adoption of the euro gave the Member States, whose sovereign credit ratings were lower than those of the strong ones (e.g. Greece, Portugal and Spain), the opportunity to borrow at much cheaper rates than in the past. This was allowed to happen based on the false assumption that their participation in the Eurozone eliminated their credit risk, since they were expected to respect the European economic rules they were now committed to [13], [14].

The combination of low interest rates and high tolerances in achieving the 'convergence criteria' led to a period of "fake" prosperity for the periphery states (Portugal, Italy, Ireland, Greece and Spain). Thanks to large infusions of liquidity and unlimited access to credit from the rest of the Eurozone, these countries started consuming more, building generous social systems and funding a construction boom instead of supporting the agriculture, strengthening the industry or investing in research and development. Consequently, when the prosperity years came to an end, they were faced with the hard truth: large amounts of accumulated debt, which was impossible to handle by themselves [14], [15], [16].

The aforementioned economic situation was camouflaged well until the global financial meltdown of 2007-2008 caused by the US financial crisis, which brought in the forefront liquidity problems. As a result, the peripheral countries were left with unsustainable deficits and public debts greater than their GDP. By 2010, a sovereign debt crisis was spreading all over the periphery, compromising the European Union's unity and economic future. Since mid-2012, due to successful fiscal consolidation, wide structural reforms implemented in the countries mostly in danger and various policy measures taken by the EU leaders and institutions, the financial stability of the Eurozone has improved significantly, thus diminishing the risk of contagion for the rest of its members [15].

2.3 The Greek debt crisis

After presenting the general context of the European debt crisis, it is time to focus on the country of Greece. In the following section, first we will dig into the origins of the Greek crisis, next we will present the major economic, political and social events that took place from the beginning of the crisis up to the present day, and last, we will propose potential solutions to tackle the problem.

2.3.1 Origins

Tracing back to the origins of the Greek financial crisis, we can distinguish two explicit types of contributing factors: the endogenous factors, relating to the structure of the Greek economy itself and the political management of the domestic finances and the exogenous factors, relating to the timing and nature of actions taken by the external bodies involved, such as the Eurozone, the European Central Bank (ECB) and the rating agencies [17].

- **Endogenous Factors**

According to economists, the outburst and sustenance of the Greek financial crisis can be blamed on a number of endogenous factors, which compose the weak political scene of the country since its foundation in 1832. Among them, the unregulated state of the economy, an ineffective public administration, tax evasion, and widespread political clientelism are the most determinant ones.

During the 1990's the upcoming entry of Greece to the Eurozone made investors, who believed in convergence among the Euro area members, gain confidence in the country. Consequently, Greece got access to cheap borrowed capital, which was, unfortunately, not directed into productive investments that would assure the country's future economic growth. On the contrary, it was used to pay for excess government spending and imports from abroad. The governmental expenditures also included raises in public sector wages and provision of more social benefits to the Greek people. The situation got even worse due to the low levels of revenues earned from taxes and exports, which were not sufficient to compensate for the government's overspending. Therefore, the Greek government budget and trade deficits amplified during the 2000's, as shown in figure 1.

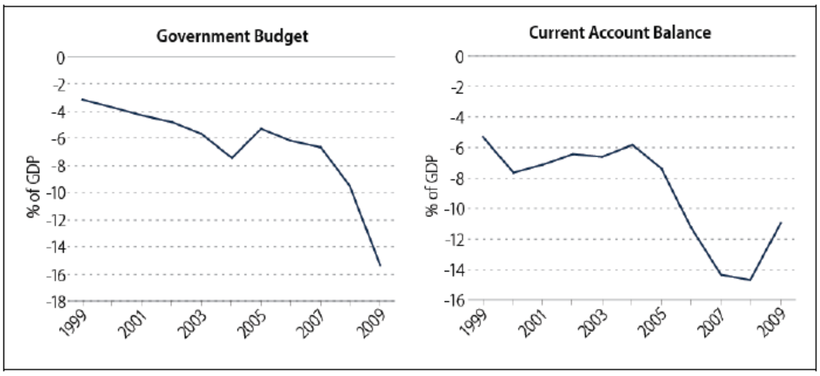

Figure 1: Greece's "Twin" Deficits: Budget and Current Account Deficits 1999-2009, Original Source: IMF, World Economic Outlook, April 2011, [18]

Following the outbreak of the global financial crisis in 2008, in mid-October 2009 the newly elected Greek Prime Minister, George Papandreou, announced that the budget deficit for the year was 12.7% of GDP instead of 6.7% reported by the previous government. The situation aggravated as the budget deficit for 2009 was revised upwards several times, taking its final figure at 15.4% of GDP. At this point it was apparent that Greece had been constantly violating the fiscal rules defined by the Maastricht Treaty and the Stability and Growth Pact. The country's governmental credibility was compromised and soon major credit rating agencies downgraded the Greek bonds. In addition, the high levels of the Greek debt made investors increasingly uncertain about the country's possibility to prevent a potential default. Consequently, they started demanding higher interest rates for buying and holding Greek bonds to compensate for the higher risk involved, as depicted in figure 2 below. All these parameters combined, put Greece in the downward trend of the ongoing crisis [18].

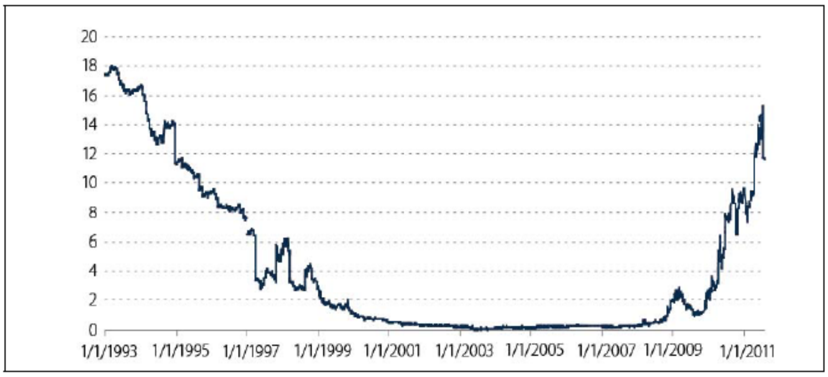

Figure 2: Greek Bond Spreads, 1993-2011 (Spreads on 10-year Greek bonds relative to 10-year German bonds (%)), Original Source: Global Financial Data, [18]

- **<u>Exogenous factors</u>**

Except for the multiple unquestioned mistakes of the Greek governments themselves over the years, a couple of exogenous factors caused by the mismanagement of the crisis by the rest of the bodies involved contributed as well to the further deterioration of the economic state of the country.

To begin with, Eurozone's indecisiveness and delayed reaction to the problem played a very crucial role. As the Greek crisis was escalating, the rest of the Member States couldn't consent on whether to provide Greece with their support. Indeed, for many of them a bailout wasn't even considered as a possible and legal solution, although the Maastricht Treaty did not exclude such possibility. As the Eurozone members couldn't decide and respond to the Greek crisis on time, the markets assumed that the EU countries couldn't give any guarantees that the Greek debt can be sustained [17].

Furthermore, the European Central Bank (ECB) created an uncertain environment regarding the ability of the Greek government debt to serve as liquidity collateral. Consequently, many institutions in possess of Greek government bonds rushed to get rid of them, as they were faced with the possibility of not being able to liquidate them. This situation speeded up even more the unfolding of the Greek crisis [18].

The last exogenous factor that affected adversely the economic status of Greece at the beginning of the crisis was the series of actions taken by the rating agencies. Having failed to predict and encounter successfully the 2007 US sub-prime mortgage loan crisis and the sovereign debt crisis of Dubai, the rating agencies started to anxiously search for other possible economic crises around the globe. Inevitably, they turned to Greece and other Southern European countries, where they began immediately the process of downgrading, as seen in figure 3. Consequently, the government bond rates of these countries rose sharply, making the corresponding economies less competitive [18].

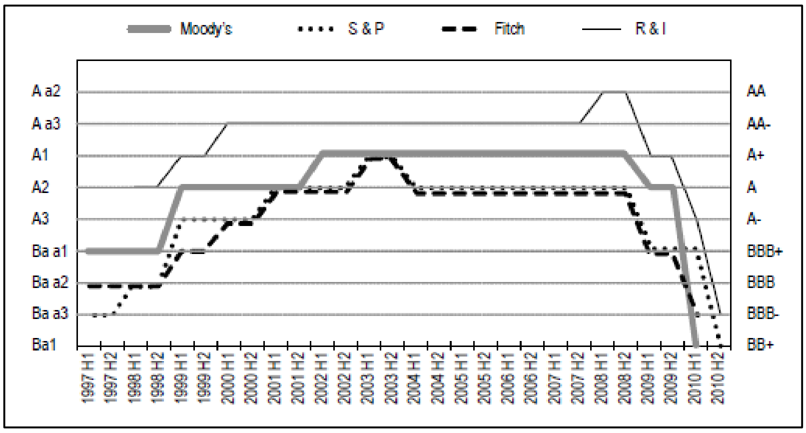

Figure 3: Credit Rating of Greek Bonds, Original Source: Public Debt Management Agency, [17]

2.3.2 Timeline

Next we present the timeline of the major economic, political and social events that took place during the Greek debt crisis, from its initial eruption and up to this day. For better clarity, the events are reported by year of occurrence:

- **<u>Year 2009</u>**

In October, Greece is driven to sudden general elections, as the current government is accused of corruption and over-spending. The Socialist party wins and George Papandreou becomes the new Prime Minister. With his rise to power, he launches the debate on "obsolete" statistics regarding the economy and the budget deficit of the country.

In December, Greece's debt of €300 billion is revealed. The Greek debt-to-GDP ratio reaches the level of 113%, far exceeding the 60% Eurozone limit. While the credit rating of Greece is downgraded by rating agencies, Papandreou withdraws his initial plan for economic recovery equal to €2.5 billion and introduces the first package of austerity measures, in an effort to reduce the deficit from 12.7% to 3% of GDP before the year 2013 [19], [20], [21], [22], [23].

- **<u>Year 2010</u>**

In January, an EU report reveals that the Greek accounting procedures demonstrate "severe irregularities". The Greek budget deficit in 2009 that was reported equal to 3.7% is now revised upwards to 12.7%, from 3.7%, surpassing by more than four times the maximum allowed by EU rules.

On March 3rd, Mr. Papandreou still argues that Greece will not need a bailout. However, under pressure from markets and European partners, his government presents a second package of austerity measures to unfreeze €4.8 billion. The austerity measures to be imposed in Greece spark strikes and riots in the streets.

On May 2nd and after months of reluctance, the EU, the International Monetary Fund (IMF) and Greece agree on the first Economic Adjustment Program, a €110 billion rescue package for three years, of which €80 billion are borne by the Eurozone Member States and €30 billion are loaned by the IMF. In return for the aid package, the government begins a third austerity program of €30 billion savings, which includes changes in tax hikes, public service pay-cuts and pension reforms. Meanwhile, protesters flood the streets of the Greek capital, Athens, and the demonstrations turn violent. Three people lose their lives, trapped in a bank set on fire by demonstrators. During the same month, the EU creates the European Financial Stability Facility

(EFSF), whose aim is to provide monetary assistance of up to €750 billion to Member States in difficulty [19], [20], [21], [22], [23].

- **Year 2011**

In February, the Eurozone finance ministers create a permanent crisis resolution mechanism for the countries of the euro area, called the European Stability Mechanism, worth about €500 billion. The ESM issues debt instruments in order to finance loans and other forms of financial assistance to euro area Members States.

In June and after long negotiations, the Greek parliament adopts a fourth austerity plan of €28.4 billion for four years, which was dictated by the IMF and the EU in exchange for the payment of the fifth tranche of the bailout program.

On July 20th, the IMF, EU and ECB, known also as troika, agree to provide a second bailout package of €158 billion, of which €109 billion will be allocated between the IMF and the European Financial Stability Fund (EFSF) in the form of loans.

On September 21st, the Greek government announces more austerity measures in order to release the sixth tranche of the first international aid package given in 2010. The new measures, which negatively affect pensioners, civil servants and taxation levels, are expected to save €7.5 billion more.

On October 27th, EU leaders agree to force private investors to accept a "haircut" on Greek bonds. The requirements are reduced by 50% and €30 billion become available to the banks. A new aid package in the form of loans up to €100 billion is granted to Greece replacing the program of €109 billion decided in July. In return, Greece should accept stricter controls on fiscal policy. On 31st of October, Greece faces a political crisis. The Prime Minister, George Papandreou, proceeds to a surprise referendum regarding the Oct. 27th bailout agreement. A week later, faced with internal and external criticism, he withdraws his proposal and resigns. As a result, a national unity government is created to manage Greece through the crisis. A technocrat, former governor of the Bank of Greece, Lucas Papademos, assumes the premiership [19], [20], [21], [22], [23].

- **Year 2012**

On February 13th, Lucas Papademos seeks the adoption of a sixth austerity plan to fill a budget-hole of €350 million, which, if not covered, threatens the country with default. However, the receipt of new rescue funds means that further austerity measures need to be realized: the minimum wage should decrease by 22%, the pensions should be cut off by 15% and the private sector jobs should be reduced by 15,000 positions. At that moment, unemployment in Greece reaches the unprecedented high level of 21%. On 21st of February, the Eurozone foresees the second Economic Adjustment Program for Greece with financial assistance of €164.5 billion (the undisbursed amounts of the first program plus an additional €130 billion) until the end of 2014, a period which was later extended to the end of June 2015. Of this amount, the euro area commitment amounts to €144.7 billion to be provided via the EFSF, while the IMF contributes €19.8 billion.

On 6th of May, the result of the national elections in Greece shows that the majority of Greeks are against the country's bailout agreement with the EU and International Monetary Fund. The elected parties cannot form a coalition and new elections are called for 17th of June.

On June 17th, the national Greek elections are held once again, with the center-right party named "New Democracy" finishing first and forming a three-party coalition. Its leader, Antonis Samaras, becomes the new Prime Minister.

On November 7th, the conservative new-elected government requests approval of the seventh austerity program amounting to €18 billion by the parliament. The troika imposes the implementation of this program in order to release monetary aid of approximately €30 billion, coming from the EU and the IMF. On 27th of November, the finance ministers of the Eurozone along with the IMF agree on a reduction of €40 billion of the Greek debt and a ten-year postponement of the interest repayments. The debt is expected to fall to 124% of GDP in 2020, compared with 120% that was the initial expectation of the IMF [19], [20], [21], [22], [23].

- **Year 2013**

On 8th of July, Greece receives the eighth loan equal to €2.5 billion plus a further €500 million in October, as decided by the Eurozone finance ministers, in order to prevent a new outburst of the debt crisis. However, the Greek government is still under pressure to further cut down on jobs and public spending. Additionally, the European Central Bank is to return €2 billion in profits earned from Greek bonds, while the International Monetary Fund is expected to supply €1.8 billion in August [19], [20], [21], [22], [23].

- **Year 2014**

On April 10th, Greece returns to international financial markets with its first issue of Eurobonds in four years. The government raises €3 billion in five year bonds, with an initial yield of under 5% percent, which is seen as a good mark for the economy. In another sign of renewed investor confidence, the offer raises €1 billion more than expected [22], [23].

- **Year 2015**

On 26th of January, the coalition of the radical left SYRIZA wins the general elections. The new Prime Minister, Alexis Tsipras, starts a new round of tough negotiations with the Europeans and the IMF in order to ease the austerity measures, rearrange the Greek debt and release the last tranche of international aid package, which would allow Greece to meet its obligations towards its European partners.

On 26th of June and after months of discussions, the negotiations between Greece and its creditors take a dramatic turn, while approaching the critical date of 30th June, when the country has a deadline to pay one more tranche to the IMF or find itself in default. While the Greek government insists on denying the conditions defined by the EU, the Europeans send an ultimatum. The Greek Prime Minister requests a referendum on July 5th putting the decision of accepting the European proposal in the hands of the Greek people, while simultaneously he advises them to vote against it. The government temporarily closes the banks to prevent massive capital flows and imposes capital controls. Following the Prime Minister's advice, 61.31% of the Greek people vote against the creditors' proposal.

In August, Greece and its creditors agree on a third bailout worth €86 billion, imposing further spending cuts on the country to avoid bankruptcy and exit from the Eurozone [22], [23].

- **Year 2016**

During this year, one more problem that needs immediate attention is added to the difficult portfolio of the Greek government, the refugee crisis. In March, the Eurozone finance ministers agree to unlock a further €10.3 billion in loans, a tranche of cash that Greece needs to meet debt repayments due in July. They also agree on debt relief for the country, extending the repayment period and capping interest rates. In May, a new austerity package to the tune of €5.4 billion is approved by the Greek parliament [22], [23].

2.3.3 Possible Solutions

Despite the efforts of the EU to assist Greece by granting loans and imposing specific state-reforming measures, the country's economic state is still unstable, mainly because the actions taken constitute short-term solutions to the problem. It can be argued that the Greek economy needs more time to show certain signs of recovery, the Greek people still struggle under the burden of austerity and the unemployment levels remain high [18].

From figure 4 it can be seen that Greece entered 2015 with an estimated debt-to-GDP ratio of approximately 177%, succeeding the previous year when the same ratio was higher and equal to 180%. However, predictions suggest that this indicator has an upward trend, which means that the country will still have to spend a high proportion of its annual GDP and government revenues just to repay the interests of all EU/IMF loans received over the last years. In figures 4 and 5 the unfolding of the crisis over the period 2010-2020 (the values for the period 2016-2020 are estimates) is depicted by presenting data relating to the national debt and GDP. Additionally, figure 6 gives a collective image of the country's economic state from 2010 to 2015 by presenting the corresponding revenues and expenditures [24].

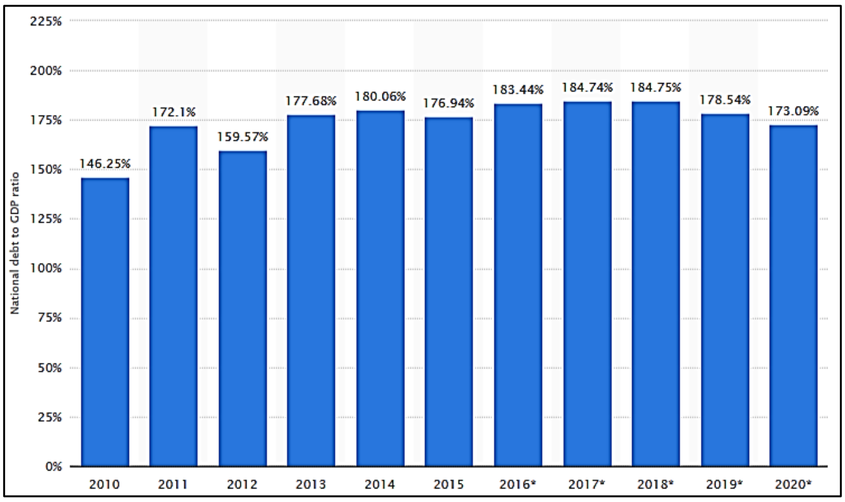

Figure 4: Greece's national debt in relation to gross domestic product (GDP) from 2010 to 2020, [25]

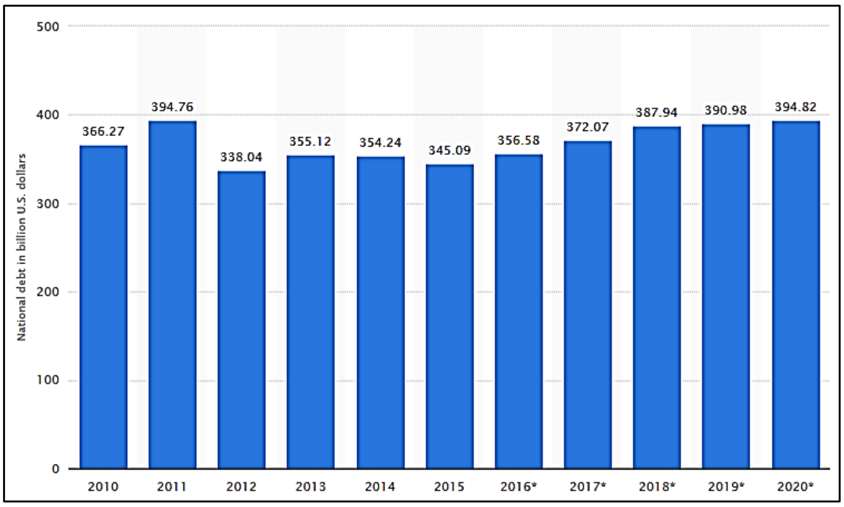

Figure 5: Greece's national debt (in billion US dollars) from 2010 to 2020, [25]

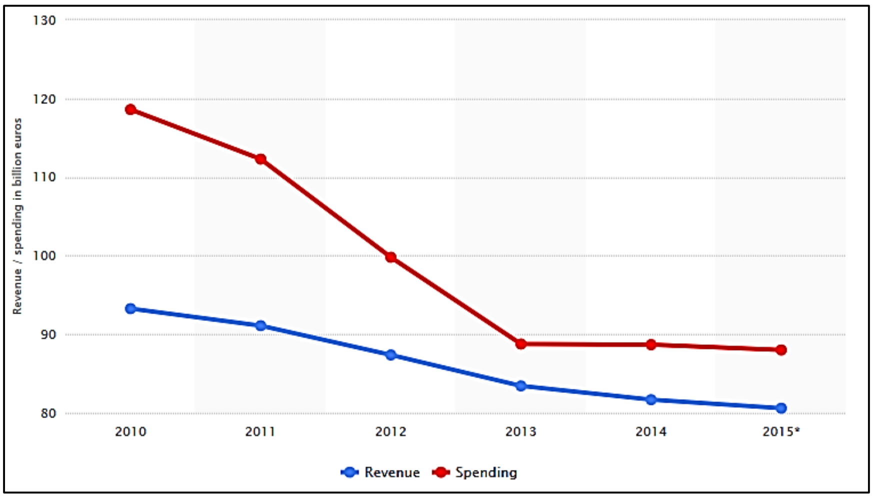

Figure 6: Greece's government revenue and spending (in billion euros) from 2010 to 2015, [25]

Undoubtedly, such a debt level is unsustainable. However, proposing a specific solution to the Greek economic crisis is far from the scope of analysis of this thesis. Therefore, in the following section a selection of different approaches on how to handle a national debt will be presented briefly for the sake of completeness of the current chapter.

The various methods of addressing a national debt are summarized below:

- **Use Quantitative Easing (QE) policies with the help of a Central Bank to monetize effectively the government debt:**
  The implementation of this method creates higher inflation rates that in turn reduce the real value of debt and accommodate its easier payback. However, the growth is achieved at the cost of domestic consumers who suffer a loss of purchasing power and a degradation of their living standards, at least until the economic balance is set again. This option is unsuitable for Greece, since it can only be applied in countries using their own currency [24].

- **Grow the GDP much faster than the debt so that the Debt-to-GDP ratio will shrink over time:**
  Although it is one of the most preferable methods, it has two significant drawbacks: it is long-term to implement and highly ineffective in cases of excessive debts, such as the Greek debt. In order for this method to be successful for the case of Greece, the GDP would have to grow at very high annual rates to cover the loans' repayments and account for economic growth. So, unless the Greek private sector improves its productivity rapidly or the current account deficit converts to a sustainable surplus, this is not a suitable way to overcome the Greek crisis [24].

- **Save through the implementation of austerity measures and repay the debt with the assistance of EU/IMF loans:**

  This is the solution accepted by the Eurozone members and currently implemented by the Greek government. However, the EU/IMF assistance loans come at a cost of severe austerity measures and reforms for the state. Indicatively, we can mention that salaries have been suffering cuts of 20%-40%, more than 150,000 civil servants have been dismissed, state pensions have been reduced permanently and many public corporations have been privatized. Economists, such as Alberto Alesina and Silvia Ardagna, claimed that austerity in the long run might make exports cheaper (through internal devaluation), increase profits and thus stimulate investment. However, later research by other economists (Baker, Frankel, etc.) and actual implementation of the method proved that all those steep cuts in government expenditures have been contracting the Greek economy rather than helping it to expand and recover [18], [24], [26], [27], [28].

- **Restructure the debt:**

  Restructuring a national debt for either the private or the public sector can contribute significantly to the recovery of heavily indebted economies. In the case of Greece, the original EU assistance program didn't include any debt restructuring, believing that it could potentially harm the stability of the Eurozone. However, as the state of the Greek economy got worse month by month, on 21st of July 2011 the EU leaders decided to proceed with a 21% debt restructuring, which foresaw the postponement of the debt repayment. The ineffectiveness of the measure made Eurozone members realize that the consequences of a possible Greek default could be much more severe than the ones resulting from a deeper debt restructure and its predictable losses. Hence, on 26th of October 2011 they concluded in the Brussels's Agreement, which focused on a voluntary 50% reduction of the face value of the debt issued before May 2010. However, even so, the Greek debt still remains at high levels and little can be changed with the introduction of a new debt restructuring scheme [24].

- **Default:**

  With regards to the Greek government debt crisis, the term "default" refers to the situation where Greece defaults on its debt, exits the Eurozone and returns to the its former national currency. Economists have much debated on the matter of defaulting. Some of them strongly believe that a default would relieve Greece of its current binding obligations towards its creditors: to repay its debt, while putting up with severe austerity measures. Moreover, an exit from the Eurozone would mark the country's return to its former national currency, the drachma. Having its own currency back, Greece would be able to depreciate it, which in turn would make export prices decrease, thus the exports themselves would increase, inflowing more cash into the nation. As the supporters of this view argue, of course such a default would bear costs in the short run. However, these costs would still be more manageable than the "many years of recession, stagnation, and high unemployment the European authorities are offering". Other economists believe that exiting the Eurozone would be painful, as this situation could lead to the creation of capital flight, bank runs, bank-savings destruction, black markets and significant inflation, due to the increased cost of imports. Moreover, a solution like this could make future borrowing by both the public and private sectors more expensive, forcing the government to comply with some sort of austerity of its own. In addition, a potential "Grexit" could be contagious for other Member States as well. This could jeopardize the stability of the Eurozone, which in turn would have a negative influence on international markets [24], [18], [27], [28].

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Chapter 3: Greece and Its Energy Sector

The adverse consequences of the Greek debt crisis are evident in every sector of Greece's economic activity. Unfortunately, the energy sector couldn't be an exception. However, the development of this sector could have significant direct and indirect effects on the recovery of the Greek economy on both national and international level. Therefore, Greek energy policy is an important tool that can restore the country's economic growth. In this regard and despite the current stagnation caused by the crisis, the Greek government is making serious supporting steps to boost the energy market by taking initiatives to liberalize it, ease the regulatory framework, limit bureaucracy, and generally create more attractive conditions for private investors, both native and foreign, to invest. Thus, it could be argued that the Greek energy market is mature enough to support new investments and guarantee that they can be profitable and secure despite the crisis [29], [30], [31].

In the following subchapters, the current energy landscape of Greece will be presented in detail, focusing on Renewable Energy Sources (RES) and especially on Solar Energy. Furthermore, energy policy issues, such as the relevant legislation and institutional framework, as well as supporting energy measures, namely subsidies and Feed-in Tariffs, regulating the Greek energy sector will be discussed. Lastly, the main goals the country needs to meet by the end of 2020 along with a brief roadmap showing the expected targets up to 2050 will be presented.

3.1 The Greek Energy Landscape

In recent years the picture of Greece's energy landscape has changed radically. The two main reasons of this alteration are the development of new advanced technologies and people's growing concern about environmental issues, reasons that are even more imposing by the country's participation in European, international and other intergovernmental unions. More specifically, processes such as the liberalization of the electricity and natural gas markets via the implementation of the specific "Law 4001/2011", the expansion and amplification of the domestic and trans-boundary energy networks, the reforming of energy production by increasing Renewable Energy Source's share instead of fossil-fuel's share, the improvement of energy efficiency and saving, the increase in environmental awareness and protection and last but not least the reinforcement of competitiveness are essential for bringing the Greek energy market up to date with the rest energy markets of the world [32].

A comprehensive analysis of the Greek energy situation requires the studying of the behavior of basic supply and demand fluctuations for all energy sources in a way that will allow the easy comparison of their contribution to the economy and will depict the interactions between them when converted from one form of energy to another [33]. The two terms most accurately describing these varying energy data are total primary energy supply and total final consumption.

Total primary energy supply (TPES) is indicating the energy inputs into an economy. It is the sum of the diverse primary energy resources of a country namely fossil fuels, natural gas, renewables, nuclear energy and heat. TPES combined with indicators of population, economic wealth, or greenhouse gas emissions, can give insight in economic efficiency issues, depending on the local social, economic, and geographic factors. According to the International Energy Agency (IEA), TPES's formal definition is the following: TPES = indigenous production + imports – exports – international marine bunkers – international aviation bunkers ± stock changes [34]. Total final energy consumption (TFC) is the total amount of energy consumed by end users. In other words, the term covers the energy quantities consumed by private households, commerce, public administration, services, agriculture, industry and fisheries but excludes the ones used by the energy sector itself [35]. Comparing the two terms, it turns out that TFC is, in fact, the TPES decreased by the amount of energy needed for the transformation of primary energy sources, such as crude oil, into forms suitable for end use consumers such as refined oils, electricity, etc. Transformation refers not only to the energy losses of the processing itself but also to those occurring during the energy distribution from the generating/production point to the final users, a quantity known as "energy overhead". Between TPES and TFC, the first one provides a more comprehensive indication of the impact of the individual sectors on energy use and on energy-related CO_2 emissions. In order for the terms to be directly comparable, all the relevant energy commodities are converted to tons of oil equivalent (toe) using standard coefficients for each energy source [36].

As far as the total primary energy supply is concerned, it was estimated to be equal to 27 million tons of oil equivalent (Mtoe) in 2010, showing 8.2% decrease comparing to 2009 and a 11.1% decrease comparing to 2008, in contrast to the period 1990-2008, when it increased on average by 2% per year, while the corresponding increase of the GDP was more than 3%. At 2010, the country's energy needs and the entire indigenous production relied by one third on domestic sources, mainly lignite but also renewable energy, and by two-thirds on oil and natural gas, almost entirely imported from abroad. Amongst them, oil still remains the most prevalent energy source in Greece, with a diminishing share in TPES from 77% to 52% between the years 1973 and 2010. Lignite follows with a share of 27% of TPES in 2010 and plays the leading role in electricity production. The third biggest contributor in the energy sector with a fast growth over the last decades is natural gas, accounting for 12% of TPES in the same year. Summing up the total share of fossil fuels to the TPES in 2010, gives us the percentage of 91%, one of the highest among the IEA members. On the other hand, energy supply from renewable sources isn't sufficiently widespread yet. More specifically, biofuels and waste provided 4%, hydropower 2%, solar and wind energy less than 2% of TPES in 2010 [29].

Table 1: Detailed contribution of Greek Energy Sources as a percentage of TPES at years 1973, 1990, 2000, 2007 and 2010, [37], [29]

Energy sources (shares % of TPES)	1973	1990	2000	2007	2010
Coal	17.8	37.6	33.4	29.2	27.0
Peat	-	-	-	-	-
Oil	76.7	56.3	54.9	52.6	51.8
Natural Gas	-	0.6	6.3	11.1	11.8
Biofuels & Waste	3.8	4.2	3.7	3.9	3.8
Nuclear Energy	-	-	-	-	-
Hydropower	1.6	0.7	1.2	0.7	2.1
Wind Energy	-	-	0.1	0.5	0.7
Geothermal Energy	-	-	-	-	0.1
Solar Energy	-	0.3	0.4	0.5	0.8
Electricity Trade	-	0.3	-	1.2	1.9

As far as total final consumption is concerned, it was estimated to be 20.6 Mtoe in 2009. The effect of the economic crisis is evident, causing TFC to follow a similar progress to that of TPES. In other words, during years 1990-2007 TFC increased on average by 2.5% annually but from 2008 to 2009 there was a significant decrease of 2.8%. Once again, oil is the most important fuel with a share of 65% of TFC in 2009, a share that has not changed a lot over the years. The dominance of oil is obvious in all energy consumption sectors, bringing Greece in the first place in oil use among the IEA members and in the second place among the OECD members. The second most common energy source is electricity with a rising contribution of 17% in 1990 to 23% of TFC in 2009. This share is partitioned between the service sector with 41%, the residential sector with 33% and the industrial sector with 26% of the total consumption of all electricity. The rest 12% of TFC is covered by other energy sources, with natural gas and coal used in industry and renewable energy in individual households for heating water [29].

Table 2: Detailed contribution of Greek Energy Sources as a percentage of TFC at years 1973, 1990, 2000, 2007 and 2009, [37], [29]

Energy sources (shares % of TFC)	1973	1990	2000	2007	2009
Coal	6.1	8.4	4.8	2.4	0.8
Peat	-	-	-	-	-
Oil	75.8	67.5	67.3	65.7	65.4
Natural Gas	-	0.7	2.0	3.9	5.2
Biofuels & Waste	5.3	6.2	5.1	5.2	4.5
Geothermal Energy	-	-	-	0.1	0.1
Solar Energy	-	0.4	0.5	0.7	0.9
Electricity	12.8	16.9	20.1	21.8	22.9
Heat	-	-	0.2	0.2	0.2

As the thesis focuses on RES and especially solar energy, it is essential to take a more in-depth look at their contribution to the Greek energy landscape. Over the past two decades they showed a stable growth, accounting for an average amount of 5% - 6% of the country's TPES. This share reached the remarkable percentage of 7.5% in 2010. Figure 7 describes schematically the above mentioned estimates.

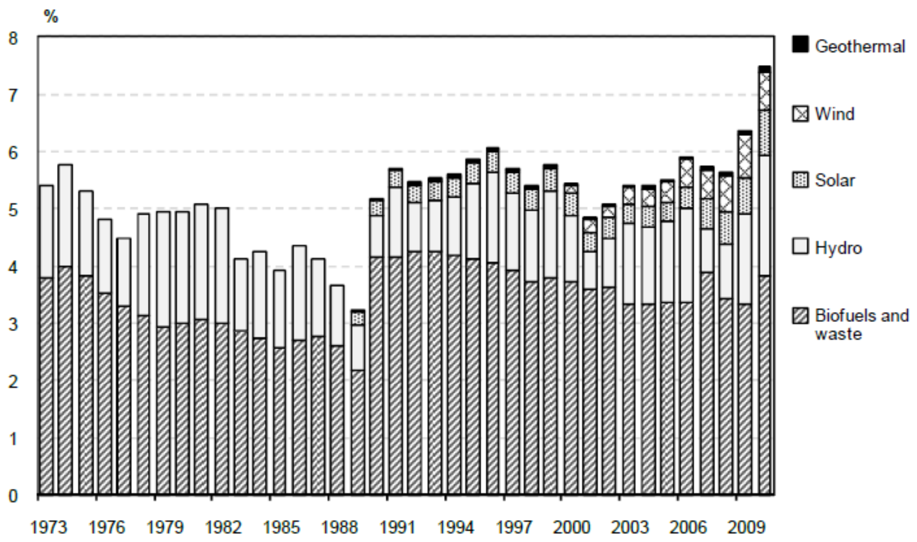


Figure 7: Renewable energy as a percentage of total primary energy supply, 1973 to 2010, 2010 estimates, [38]

Regarding the total energy production of the country, which includes both primary and secondary energy sources, the share of RES was equal to 21% in 2009. Among the renewable sources, biomass and waste were the most efficient, supplying in total 1 Mtoe of energy. The terms biomass and waste refer to fuel wood (29% of renewable energy supply), vegetal waste (14%) and liquid biofuels (4%). Hydropower contributed 28% to the total renewable supply (6.6 TWh), with a share in TPES fluctuating between 0.6% and 2.1%, depending on the hydrological conditions. Wind and solar energy showed a quick and equal growth over the years. By the end of

2009, Greece ended up in the 7th highest position of wind power supply among the IEA member countries. As for solar energy, its most prevalent use is for the direct heating of water, while its contribution to electricity generation is still insignificant. In the period 1999-2005, the solar thermal energy supply was about 0.1 Mtoe annually and in 2010 it doubled to 0.2 Mtoe, accounting for 0.8% of TPES, putting Greece ahead of Spain with 0.6%, Germany and Austria with 0.5% of TPES. In total, the use of the final amount of primary renewable energy produced in Greece is divided by 40% in buildings for heat and by almost the same percentage for electricity generation. Industry and agriculture exploit the remaining amount [24].

Table 3: Contribution of the Greek Renewable Energy Sources as a percentage of the Total Renewable Energy Supply of the country at year 2010, [29]

Renewable Energy Sources (shares % of renewable energy supply)	2010	
Biomass	Fuel wood	29
	Vegetal waste	14
	Liquid biofuels	4
Hydropower	28	
Wind Energy	25	
Geothermal Energy		
Solar Energy		

To sum up, Greece is still characterized by a quite low share of total renewable energy sources in TPES compared to the rest of the IEA countries, as figure 8 depicts:

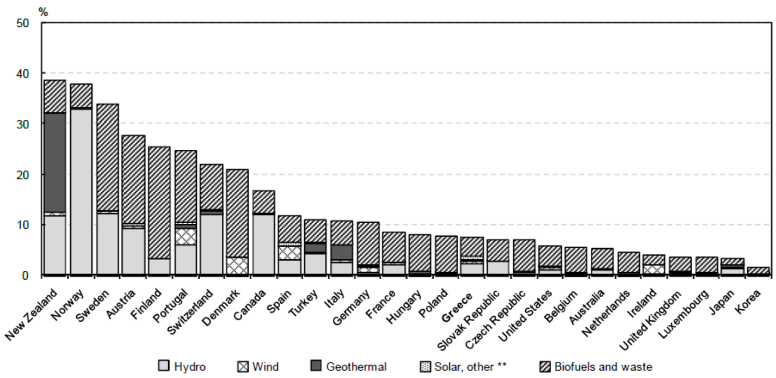


Figure 8: Renewable energy as a percentage of total primary energy supply in IEA member countries, 2010 estimates, [38]

Indicatively, electricity generated by RES forms a percentage of 15% generation in 2010, while the IEA average was 17.7%, as seen in figure 9 below:

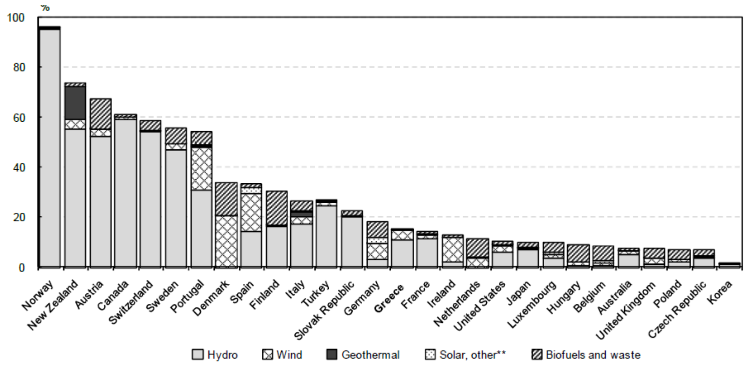


Figure 9: Electricity generation from renewable energy as a percentage of all generation in IEA member countries, 2010 estimates, [38]

The crisis has definitely taken its toll on the further development of sustainable technologies. However, the country has large untapped renewable energy resources, which once exploited can boost the national economy [24].

3.2 Renewable Energy Policy & Measures

In the case of Greece, renewable energy policy is guided by European Union's requirements. During the past few years and in cooperation with the EU Member States, the country has performed a series of essential institutional reforms and has adapted policy measures towards the achievement of a "green" development. These reforms and policies are presented below.

3.2.1 Renewable Energy Legislation & Measures

The first and most important institutional reformation was the establishment of a new **Ministry of Environment, Energy and Climate Change** (MEECC) so that all the actors engaged in the licensing processes of power plants can be gathered under one unified administration, responsible for energy, environmental and fiscal issues, including the long-term addressing of climate change. Such an institutional restructuring serves the more efficient use of the existing energy potential, while at the same time ensures the preservation of the Greek natural environment [29].

Regarding energy policies, Greece came in compliance with the international energy targets initially set by **the Kyoto Protocol**, an international agreement, which commits its parties by setting binding greenhouse gas (GHG) emission reduction targets. It was signed in Kyoto, Japan, on 11th of December 1997 and came into force on 16th of February 2005 [39]. In fact, it represents the first systematic attempt to maintain atmospheric GHG-concentrations at levels low enough to prevent dangerous anthropogenic damages to the climate. Among the greenhouse gases carbon dioxide (CO_2), which is produced almost entirely from energy processes, is the most important one. Thus, the further development of RES technologies is necessary in achieving the required reduction of emissions [40]. According to the protocol and during its first commitment period (2008-2012), Greece agreed to reduce the maximum amount of its GHG-emissions (measured as the equivalent in carbon dioxide) by 8% comparing to the relative amount recorded by the base year 1990. Unfortunately, in April 2008 the country was suspended from the mechanisms as the national system couldn't fulfill its commitments. However, in November 2008 the United Nations Compliance Committee reinstated Greece in the Emissions Trading System of the Kyoto Protocol, following a positive review. In December 2008, Greece again as a party of Kyoto's climate and energy package, agreed to reduce by the end of 2020, by 4% more its emissions comparing to the ones of 2005. Currently, the country is in line with all the international standards and preconditions of the Kyoto protocol, due to the governments' renewed policies and the raising awareness of the people [41].

Another policy influencing the Greek energy planning is the **Renewable Energy Directive 2009/28/EC** of the European Commission. This is a directive compiled by the European Parliament and Council on 23rd of April 2009, concerning the Member States of the EU and promoting the use of energy produced by renewable energy sources. According to the Directive, the EU committed itself to reach a 20% share of renewable energy in final energy consumption and a 10% share of renewable energy in transport by 2020. Moreover, every Member State has to achieve individual targets for the overall share of renewable energy in energy consumption. Therefore, participating countries are required to establish rules, for example regarding the improvement of the electrical grid access produced or the administrative and planning procedures of renewable projects. As about biofuels used in the transport sector, there is also a set of sustainability requirements needed to be met and included in the national legislation. The regulatory framework specified by this Directive is a key element for achieving the final targets. As a Member State taking part in the Directive, Greece committed to increase its renewable share from 6.9% in 2005 to 18% in 2020 [1]. A short overview of the Greek targets implied by the Directive, are shown in the following table 4:

Table 4: National overall targets for the share of energy from Renewable sources in Gross Final Consumption of energy in 2005 and 2020, [1], [42]

Overall Targets	Shares
Share of RES in Gross Final Energy Consumption in 2005	6.9 %
Target of RES in Gross Final Energy Consumption in 2020	18 %
Expected Total Energy Consumption in 2020	24114 ktoe
Expected energy amount from Renewable Sources (corresponding to the 2020 target)	4341 ktoe

The next step towards achieving the energy targets was the adoption of the **National Law L3851/2010** by the Greek Parliament. The European Renewable Energy Directive 2009/28/EC, as already mentioned, indirectly created the need for every Member State to modify its national legislation in such a way so that the final energy targets required could be realized. For Greece such alterations were transposed into the national legislation via the Law 3851/2010, which came into force on 4th of June 2010. Aiming to "speed up" the development of renewable energy's utilization in order to address climate change, the law imposes that by the end of 2020, renewable energy technologies should contribute [43]:

- A share of 20% of the gross final energy consumption, a target even more ambitious compared to the corresponding one of the Directive
- A share of at least 40% of the gross final consumption of electricity
- A share of at least 20% of the final consumption of energy used for heating and cooling and
- A share of at least 10% of the final consumption of energy used for transportation.

A more comprehensive presentation of the expected RES utilization trajectory in Greece for the period 2010-2020 and under the obligations of both the European Directive 2009/28/EC and Law 3851/2010 are depicted in the following figures. The data, shown on figures 11 and 12, concern only the electricity generation sector, as this is the main objective of the thesis.

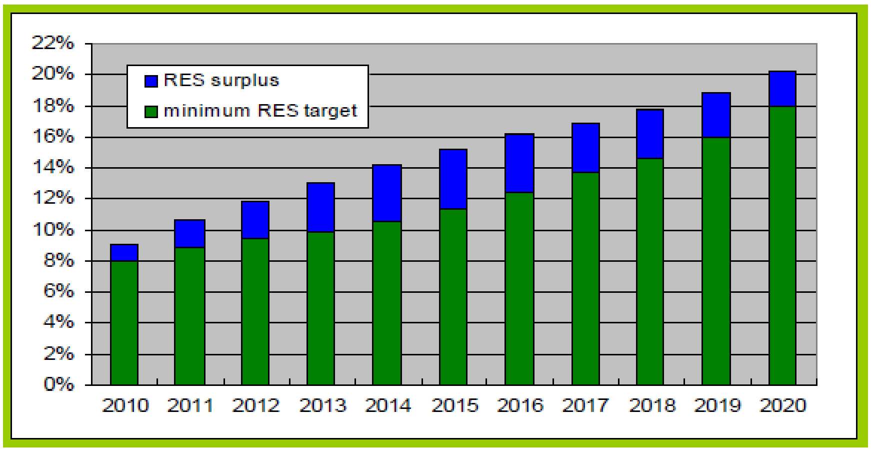


Figure 10: Trajectory of RES in Gross Final Energy Consumption until 2020. Minimum RES target refers to the Directive 2009/28/EC and RES surplus to the national Law 3851/2010, [42]

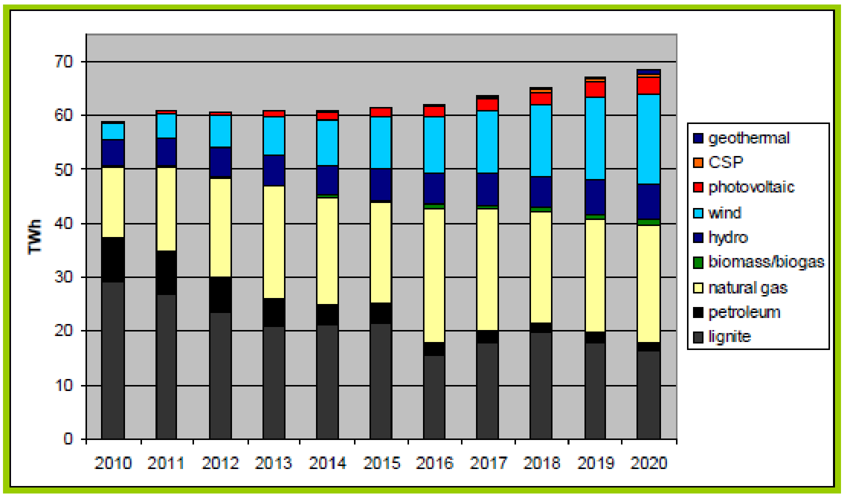


Figure 11: Estimated electricity generation from the different technologies/fuels to 2020, [42]

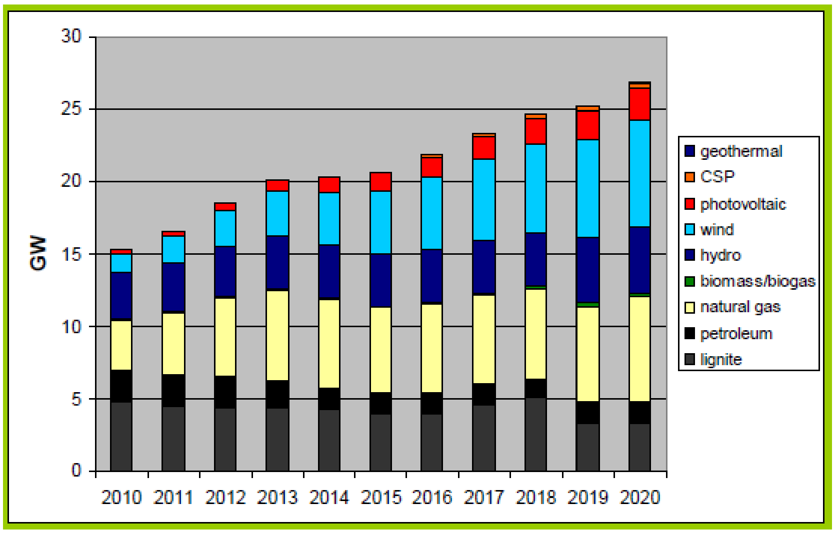


Figure 12: Estimated installed capacity of the different RES technologies for electricity, [42]

Regarding the already existing Greek legislation, the addendum of this law contributes to the simplification of the licensing procedures, the redefining of the policy mechanisms promoting investment in RES technologies such as the feed-in tariff system, boosts RES projects at local level and sets specific regulations for the use of renewable energy in buildings. The corresponding policies and regulations are cited in detail in the National Renewable Energy Action Plan (NREAP), a report compiled by decision of the former Minister of Environment, Energy & Climate Change, Ms. Tina Birbili, in November 2009 and under the supervision of the National Committee for Meeting 20-20-20 Targets and Other Requirements (20-20-20 Committee). NREAP examines three scenarios with differing results for final energy consumption, renewable energy contribution and capacity. All the elements used for the necessary estimations are based on the economic forecasts mentioned in the Greek recovery plan, known as the “Stability, Development and Reconstruction Program”. The first scenario is the “Reference” scenario and takes into account only the energy efficiency, growth rates and savings measures adopted before 2009 for the calculations required. The second scenario is called “Compliance” scenario and its implementation results in the successful achievement of the Greek energy targets in compliance to the European planning. According to that scenario, it is assumed that after an initial 3-year period of stabilization, the expected economic growth will follow a modest rate of development, with a peak of 2.7% in 2015, and will be preserved at the same levels with a slight increase to 2.9% by 2020 and a slight decrease later on till 2030. In order to cover all possibilities, a third more optimistic scenario with accelerated recovery rates is also examined, called the “Accelerated Economic Recovery” scenario. According to that, the growth indicators after 2015 increase to 4% to compensate for the reduction in demand in the first 5-year period and maintain similar or slightly lower levels for the rest of the period of interest [29], [42], [44]. The specific targets of each scenario are given in more detail in the following table 5:

Table 5: Main projections for 2010-2020 in the National Renewable Energy Action Plan by scenario, [29], [42]

	2010			2015			2020		
	Reference	Compliance	Accelerated economic recovery	Reference	Compliance	Accelerated economic recovery	Reference	Compliance	Accelerated economic recovery
Electricity generation (TWh)	**58.86**	**58.86**	**58.86**	**64.13**	**61.47**	**62.09**	**72.18**	**68.46**	**72.48**
Total RES electricity	**7.84**	**7.84**	**7.84**	**14.16**	**16.97**	**18.26**	**20.23**	**27.27**	**29.74**
% RES in electricity generation	13%	13%	13%	22%	28%	29%	28%	40%	41%
RES installed capacity (GW)	**4.11**	**4.11**	**4.11**	**7.13**	**8.66**	**9.33**	**9.91**	**13.27**	**14.72**
Of which									
Biomass/biogas	0.06	0.06	0.06	0.05	0.12	0.12	0.05	0.25	0.25
Hydro (excluding pumping)	2.54	2.54	2.54	2.89	2.92	2.91	2.91	2.95	2.95
Wind	1.33	1.33	1.33	3.78	4.3	4.74	6.25	7.5	8.25
Solar PV	0.18	0.18	0.18	0.41	1.27	1.51	0.7	2.2	2.9
CSP	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.25	0.25
Geothermal	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.12	0.12
Final energy consumption (Mtoe)	**21.53**	**21.53**	**21.53**	**22.2**	**21.33**	**21.56**	**24.19**	**23.08**	**24.64**
Of which									
Biomass/biogas	1.01	1.01	1.01	0.88	1.13	1.13	0.93	1.22	1.29
Solar heat	0.22	0.22	0.22	0.24	0.27	0.22	0.27	0.36	0.41
Geothermal	0.02	0.02	0.02	0.00	0.02	0.03	0.00	0.05	0.06
Ambient heat	0.02	0.02	0.02	0.12	0.13	0.21	0.19	0.28	0.36
Biofuels in transport	0.11	0.11	0.11	0.28	0.39	0.39	0.41	0.62	0.69
% RES in gross final energy consumption	**9%**	**9%**	**9%**	**12%**	**15%**	**16%**	**14%**	**20%**	**21%**

Greece's effort towards green development continues with the introduction of the **National Law 4001/2011**, also known as the "Energy Law". The law was adopted on 22nd of August 2011 and concerns the operation of Electricity and Gas Energy Markets, as well as the Research, Production and Transmission Networks of Hydrocarbons [45]. Its implementation aimed to establish a number of essential structural changes in the Electricity and Gas Energy Markets so that their competitiveness and efficiency will increase, under the provisions of the new electricity and gas directives included in the revised national legislation. More specifically, the responsibilities of the Regulatory Authority for Energy (RAE), the Transmission System Operator (IPTO) and the Public Power Corporation (PPC), companies that manage the energy issues of the country and that are going to be further described later, have been unbundled and distributed to new subsidiaries, leading step by step to the liberalization of the Greek energy market. This unbundling is the first priority of the country's energy policy, as it is a fast and effective way to further develop the network necessary to serve the sharp increase of the renewable energy penetration imposed by laws and directives. However, the complete liberalization of the energy markets, not only in terms of regulation but also in terms of ownership, also requires the privatization of the Greek government's stake in a number of energy companies, including the PPC, the Public Gas Company (DEPA) and Hellenic Petroleum (ELPE). Of course privatization is not a blanket solution to the problems of a poorly performing economy, as it also has many disadvantages. Among them, the government is no longer receiving profits; therefore, the revenue resulting from public sector enterprises becomes shortened. Furthermore, a privatized company always operates in its own interest of maximizing its profits, in contrary to a public company that primarily serves the citizens. This may also lead to price increases of services, especially if these services were previously subsidized by the government. Regarding PPC, the government announced that the privatization will take place in three stages and it will be completed by 2016. According to that planning, the first stage includes the total segregation of IPTO and PPC, a process which is expected to be concluded by the second quarter of 2014. The next stage is the establishment of a new electricity company that will begin its operation by the first quarter of 2015. The final stage involves the sale of an around 17% stake of PPC, a procedure that was expected to occur in the first quarter of 2016 [46]. The government is also planning to privatize part of the PPC-Renewables company, a wholly-owned subsidiary of PPC responsible for all of its renewable related projects and issues, as well as the National Natural Gas Transmission Operator (DESFA) as part of an unbundling process from DEPA, the company that currently owns it [31].

3.2.2 Renewable Energy Investment Subsidies

In the period 2004-2009 the Greek legislation was keen on supporting renewable energy investments through subsidies. Under the National Development Law L3299/2004, later amended by Law L3522/2006, the anticipated subsidizing ranged between 20% and 60% of the total investment costs of a renewable energy project, depending on its size and the region of installation. Regions with low income per capita and high unemployment rates benefited from the highest subsidies offered. In addition, tax deductions of about 20% of the purchase cost of the renewable equipment (with a cap of 700€ per system) were granted for small domestic renewable energy systems, initially for solar thermal, but later also for solar photovoltaic (PV) systems, small wind turbines, cogeneration systems as well as for thermal insulation of existing buildings and for switching from oil to natural gas in central heating. Due to the law's expiration in 2010, a new Development and Investment Law 3908/2011 was set into force on 1st of February 2011, promoting renewable investments (except for PV plants) through a combination of tax incentives and grants. The Greek State and the EU, by applying the Greek Operational Program for Competitiveness (OPC), detained their supporting behavior and thus, under the OPC 2000-2006, around 190€ million were granted for renewable energy investments. Unfortunately, due to the economic crisis, cuts needed to be done and as a result the current OPC running till the end of 2013, no longer provides such subsidies for RES technologies [29]. Furthermore, a special tax on consumers of renewable power was set by the Greek government in 2012 and raised in the beginning of 2013 [47].

3.2.3 Feed-in tariffs (FIT System)

Although renewable investments are no longer being subsidized from the Greek government and the EU, they are still viable and profitable thanks to the Feed-In tariff policy mechanism provided, a mechanism long used from the countries for encouraging investments in electricity generation from renewable sources. Feed-in tariffs typically make use of long-term agreements and pricing relating to the costs of production for renewable energy producers. The long-term contracts and guaranteed pricing offer great advantages for the producers as they prevent them from the intrinsic risks of renewable energy production, allowing for more diversity in RES technologies [48].

In Greece, the current tariff system was introduced by Law 3851/2010 and is characterized by increased feed-in tariffs compared to the previous corresponding ones, especially for Wind and Solar energy projects. The tariffs are long-term and apply for 20 years. As far as the actual price of the tariff is concerned, it varies depending on the technology.

According to the government planning, producers that were not favored from any capital investment subsidies will receive higher FIT rates, increased by 15% for biomass/biogas and by 20% for all the other technologies. Included in the planning is also a slight rise of the FIT for wind power generation in areas with low wind potential as well as a compensation for the producers in case the system operator decides to cut down the generation, equal to 30% of the cutback.

Special FIT rates apply to the larger Photovoltaic (PV) installations from June 2013. This separate feed-in tariff is agreed to be granted to that kind of power plants for 20 years and is subject to an annual reduction. Table 6 below, presents more precisely the relevant prices [29]:

Table 6: FIT rates applying to large PV power plants from 2013, [49]

Period	Interconnected System (€/ MWh)		Non-Interconnected System (€ / MWh)
	A	B	C
	> 100 kW	≤ 100 kW	(regardless of power)
2013 February	95	120	100
2013 August	95	120	100
2014 February	90	115	95
2014 August	90	115	95
2015 and on for each year n	$1.1 \cdot ASMP_{n-1}$	$1.2 \cdot ASMP_{n-1}$	$1.1 \cdot ASMP_{n-1}$

$ASMP_{n-1}$: Average System's Marginal Price in the previous year n-1

3.2.4 The Institutional Framework

It is evident in every sector of economic activity, including the energy sector, that the efficiency and its possible improvement are crucial issues, concerning every developed country such as Greece. As a result, the government has developed specific frameworks relating policies, regulations, legislations and strategies, implemented by the corresponding institutions and agencies, in order to overcome the various technical, financial and institutional barriers which hinder the efficiency potential from being realized [50]. These important institutions and agents involved in the energy issues of Greece are the following:

- **Ministry of Environment, Energy and Climate Change** (MEECC)

MEECC, which was formerly under the name "Ministry of Environment, Physical Planning and Public Works", was established in its current state on October 7th 2009. It is responsible for the production and administration of renewable energy in Greece. By implementing specific regulations and policies, it attempts to confront environmental problems and to adopt a new sustainable development model that will secure a better quality of life for the citizens. Its main missions are the protection of the natural resources, the improvement of life quality, the adapting to the implications of climate change and the enhancement of mechanisms and institutions for environmental governance [51].

- **Regulatory Authority for Energy** (RAE)

RAE is an independent administrative authority, which enjoys, by the provisions of the law establishing it about the liberalization of the electricity market, financial and administrative independence. The licensing of projects for electricity generation from RES is its main objective [29], [52].

- **Public Power Corporation** (PPC)

PPC is the biggest power producing and electricity supplying company in Greece, owning conventional thermal and hydroelectric power plants, as well as RES units, that cover almost 70% of the total capacity installed currently in the country (12.76 MW in 2011). After the severance of the transmission and distribution segments according to the law 4001/2011, two 100% subsidiaries of PPC were created, under the names of **IPTO S.A.** (Independent Power Transmission Operator S.A.) and **HEDNO S.A.** (Hellenic Electricity Distribution Network Operator S.A.). The responsibilities of the first company are the management, operation, maintenance and development of the Hellenic Electricity Transmission System and its interconnections, while these of the second one are the management, operation, development and maintenance of the Hellenic Electricity Distribution Network. As far as renewable energy is concerned, PPC plays an active role through its subsidiary company named "PPC Renewables S.A.", having the assets of 22 wind farms, 12 photovoltaic units and 12 small scale hydroelectric plants. The total installed capacity of all the above mentioned units, plus 9 more plants in which PPCR participates through joint ventures, account for 132 MW [53].

- **Operator of Electricity Market** (OEM)

OEM was also established following the provisions of Law 4001/2011. The company is responsible for applying the rules for the operation of the daily electricity market and may take any measures needed to achieve the sufficient and coordinated establishment of the internal energy market of the European Union [54], [55].

- **Center for Renewable Energy Sources and Saving** (CRES)

CRES is the Greek national entity for the promotion of renewable energy sources, rational use of energy and energy conservation. It lies under the supervision of the Minister of Environment, Energy and Climate Change and has financial and administrative independence. The institution's presence is evident in the fields of national and community policy and legislation, protection of the environment and sustainable development. CRES's main objectives are to accommodate the national energy planning and the formulation of energy policy, as well as to promote research and development related to renewable energy technologies [29], [56].

- **The European Commission**

The European Commission is the representative of the EU and its interests as a whole. Its main role is to propose new legislation to the European Parliament and the Council of the European Union, and once the legislation is adopted, to ensure that it is correctly implemented by the member countries. Before making any proposals, the Commission takes into careful consideration the potential economic, social and environmental effects of a given piece of legislation as well as the stakeholders' views that are involved in it. Regarding the further spread of RES technologies in Greece, the European Commission is responsible for keeping an eye on the right execution and successful achievement of the specific targets set by the European Directives [57].

- **Municipal, prefectural and regional authorities**

Last but not least, regional and local authorities are also responsible for issuing installation and operation licenses for electricity generation from RES, as well as environmental permits, affecting to a large extent all these kinds of procedures [55].

3.3 Roadmap to 2050

It is already mentioned that energy planning is a very important piece of the economic puzzle of a country. Therefore, the National Energy Strategy Committee conducted and proposed an Energy Roadmap of Greece for 2020-2050, now that the time period covered by the first National Renewable Energy Action Plan is approaching to its end. The main pillars of the new energy policies are the promotion of greater independence on imported energy, the increase of renewables’ penetration, the decrease of GHG-emissions and the protection of final energy consumers. Following the same pattern as the first NREAP, the efficiency of the proposed future energy system is estimated by examining three basic energy scenarios, the targets of which are similar and can be summarized in the next sentences:

- The total share of renewables in gross final energy consumption by 2050 should be equal to 60%-70%.
- The electricity generation from RES mature technologies should be equal to 85%-100% of the total electricity generation.

- The GHG-emissions should be reduced by 60%-70%, comparing to the corresponding amounts of 2005.
- The energy-saving measures should ensure the stabilization of energy consumption.
- A respectable reduction of oil consumption should be achieved.
- A slight increase in electricity consumption may be observed due to the electrification of transport and the wider use of heat pumps in the residential and tertiary sectors.
- The utilization of biofuels for transportation reasons should reach a level of 31% - 34% by 2050.
- Improved energy efficiency and larger penetration of RES in buildings should be reached.
- The policies and measures should enhance the development of decentralized energy production and smart grids.

It is obvious that the new energy targets, set for fulfillment in the short and long run, are highly demanding. Their achievement requires right preparation, sincere adoption, disciplined implementation and critical evaluation of a number of energy policy measures. In any case, all these efforts definitely show that Greece has the will and the potential to change significantly over the next years, to become competitive again, overcome the crisis and economically bloom [58].

Chapter 4: Photovoltaic (PV) Technology Overview & the Case of Greece

The arousing environmental concerns and the increasing demand for energy, along with the alarming depletion of conventional fuel resources, as shown in table 7, are creating new opportunities for the utilization of renewable energy.

Table 7: World proven fossil fuels' reserves and years left to their depletion, as recorded on January 1st 2013, [59], [60]

Fossil Fuels	Proven Reserves	Years Left
Oil	1.638 billion barrels	54
Natural Gas	6.793 trillion ft^2	63
Coal	946.1 billion short tons	119

Solar energy is the radiant energy (lighting and heating) produced by the Sun. As an energy source, it has the advantages of being inexhaustible, more abundant and cleaner than the rest of the renewables till date. Sun's power received by the Earth's surface is about 1.7×10^{11} MW, a number many times larger than the present rate of the global energy consumption, which is approximately 1.3×10^{10} kW. The amount of this raw power can be useful in four different fields:

- Solar thermal field: by using the solar radiation for direct heating of buildings or water.
- Solar photovoltaic field: for the generation of electricity.
- Solar biomass field: by using trees, bacteria, algae, corn, soy beans or oilseed that with the help of Sun photosynthesize and can be turned into energy fuels, chemicals or building materials.
- Food field: similar to solar biomass, except that the plants are harvested for humans or animals.

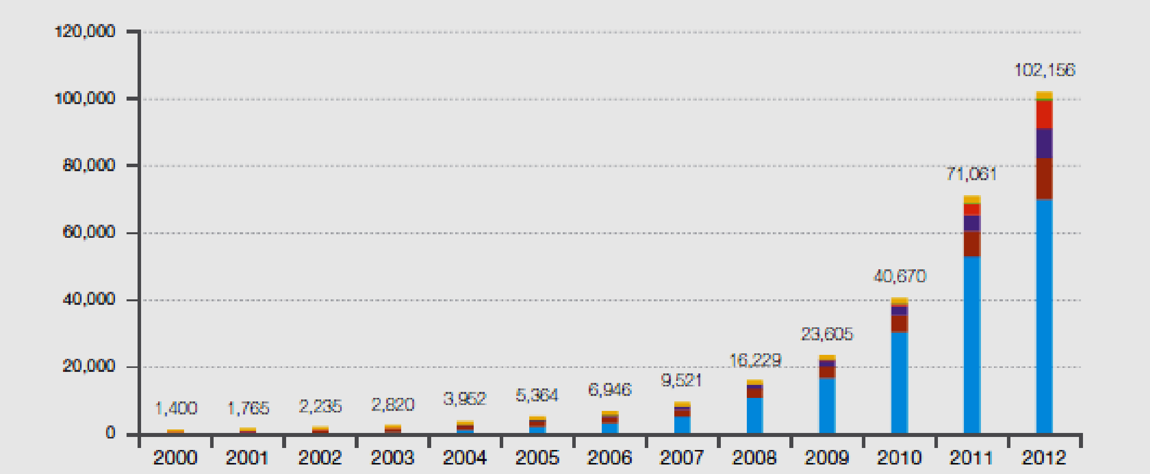
The current thesis focuses on the photovoltaic (PV) technology of large-scale, which is one of the finest ways to harness solar energy for electricity production purposes. The chapter begins with a short history of photovoltaics and continues with a detailed description of the current PV technologies; from single solar cells and their basic operation principle to PV power stations and the evaluation of their performance. Subsequently, an analysis of the past, the present and the future state of the Greek, large-scale PV sector is conducted. The licensing procedure leading to the construction and final operation of a PV station as well as the stakeholders involved are also described and depicted in the corresponding Stakeholder's Map [61], [62] .

4.1 Short History of Photovoltaics

The history of Photovoltaic (PV) Systems begins at 1839 when the French physicist Edmond Becquerel described for the first time the photovoltaic effect. He discovered that certain materials would generate small amounts of electric current after being exposed to sunlight. In the 1870's Heinrich Hertz started studying the effect in solids, such as selenium, and resulted in the first selenium PV cells, able to convert light into electricity with an efficiency of 1%-2%. However, within almost a century from that time no significant progress in PV cells was observed [63]. Therefore, we can claim that PV systems in their present form are a recently developed sustainable technology, dating back to the 1950's, when the first conventional PV cells were produced. From that time on and throughout the 1960's solar cells were initially used for providing electrical power for earth-orbiting satellites. During the 1970's, the developments in manufacturing, performance and quality of PV modules reduced their costs and created numerous opportunities for use in remote terrestrial applications of low-power needs.

In the 1980's, PV cells became famous as the power source of electronic devices such as personal calculators, watches, radios and other small battery-charging gadgets. But except for that, the oil crises of the 70's triggered even more the development of PV power systems for residential and commercial uses; both for stand-alone, remote power as well as for grid-connected applications. During the same period international applications for PV systems as the power source of rural health clinics, refrigeration, water pumping, telecommunications and off-grid households grew rapidly. The latter still plays a major role in the present global PV market.

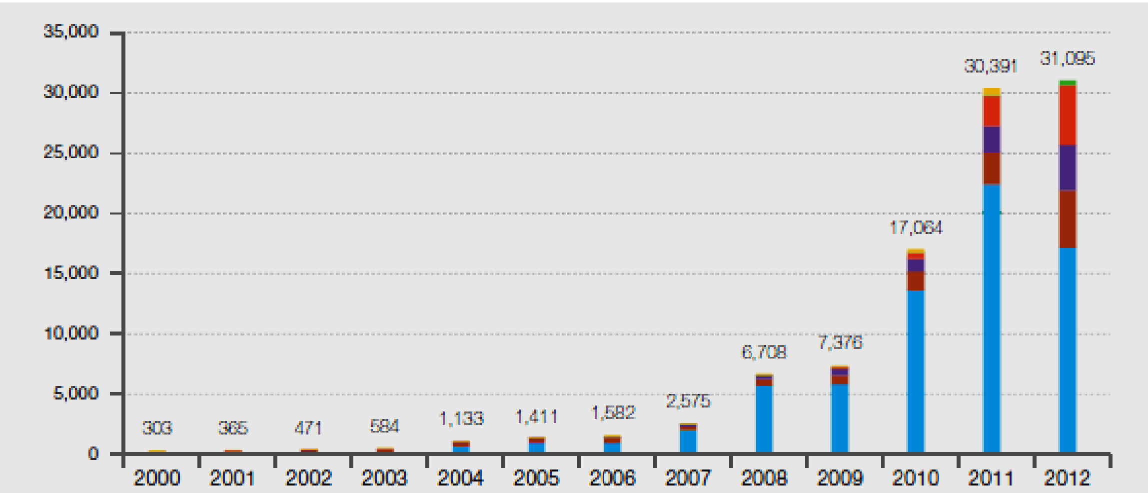
Nowadays, the industry of PV technology production shows an expansion of approximately 25% per year and through international governmental supporting schemes, the implementation of PV systems in buildings as well as their interconnection to utility networks is steadily accelerating. Over the past decade, in spite of the difficult economic circumstances, PV technology grew globally at a significant rate. At the end of 2009, the world's cumulative installed PV capacity was approximately 24 GW while one year later it reached 40.7 GW. At the end of 2011 it was 71.1 GW and in 2012 more than 100 GW, an amount capable of producing at least 110 TWh of electricity every year [64], [65]. The following figures 13 and 14 depict the global PV technology's growth over the period 2000-2012 and confirm that it is becoming a major source of power generation worldwide:



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
ROW	751	807	887	964	993	1,003	1,108	1,150	1,226	1,306	1,590	2,098	2,098
MEA	n/a	n/a	n/a	n/a	1	1	1	2	3	25	71	192	601
China	19	24	42	52	62	70	80	100	140	300	800	3,300	8,300
Americas	146	178	225	290	394	501	650	863	1,209	1,752	2,780	4,959	8,717
APAC	355	495	686	916	1,198	1,500	1,825	2,096	2,631	3,373	4,956	7,628	12,397
Europe	129	262	396	598	1,305	2,289	3,281	5,310	11,020	16,850	30,472	52,884	70,043
Total	**1,400**	**1,765**	**2,235**	**2,820**	**3,952**	**5,364**	**6,946**	**9,521**	**16,229**	**23,605**	**40,670**	**71,061**	**102,156**

ROW: Rest of the World. MEA: Middle East and Africa. APAC: Asia Pacific.

Figure 13: Evolution of global PV cumulative installed capacity 2000-2012 (MW), [65].



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
ROW	88	56	80	77	29	10	105	42	76	80	284	508	-*
MEA	n/a	n/a	n/a	n/a	1	n/a	n/a	1	1	22	46	121	410
China	19	5	19	10	10	8	10	20	40	160	500	2,500	5,000
Americas	24	32	47	66	104	106	150	213	346	543	1,029	2,179	3,758
APAC	117	140	191	230	282	303	324	271	535	742	1,583	2,672	4,769
Europe	56	133	135	202	707	984	992	2,028	5,710	5,830	13,622	22,411	17,159
Total	**303**	**365**	**471**	**584**	**1,133**	**1,411**	**1,582**	**2,575**	**6,708**	**7,376**	**17,064**	**30,391**	**31,095**

Figure 14: Evolution of global PV annual installations 2000-2012 (MW), [65].

4.2 Current PV Technologies

The current existing PV technologies are divided into three different generations, depending on the technology of the solar cells they are using. They are illustrated in figure 15 and 16:

- **<u>1st Generation</u>**

  Technologies that deal with "bulk" crystalline silicon are considered to be the 1st generation of solar cells for terrestrial applications. Crystalline silicon (c-Si) solar cell technology represents nowadays both single crystal silicon wafer-based (mono c-Si) and multi-crystalline silicon (multi c-Si) solar cells. In an attempt to enhance the solar cells' efficiency and at the same time lower their price, significant developments have been made over the past twenty years and today this technology is the most dominant in the commercial PV market. The efficiencies of c-Si solar cells vary in a range of 13% to 20 % and their expenses are dominated by material costs.

- **<u>2nd Generation</u>**

  The 2nd generation is represented by thin-film solar cells with lower efficiencies but also lower production costs. A wide variety of semiconductor materials can be used in this kind of solar cells, such as Copper Indium Gallium Diselenide (CIGS), Cadmium Telluride (CdTe), hydrogenated amorphous Silicon (*a*-Si:H) combined with hydrogenated microcrystalline Silicon (μc-Si:H) and thin-film polycrystalline Silicon (*f*-Si). Thin-film PV technologies currently represent 10% to 15% of the global PV module production. In this generation are also included emerging PV technologies, such as the organic solar cells, which are about to enter the market in niche applications.

- **<u>3rd Generation</u>**

  The 3rd generation of solar cell includes all the novel PV concepts intending to achieve high efficient solar cells with the use of advanced materials and new conversion processes. All these concepts are currently the subject of basic research. Concentrator technologies (CPV) are a great example of that generation of solar cells. Their function is based on an optical concentrator system which collects solar radiation in a small high-efficiency cell [66].

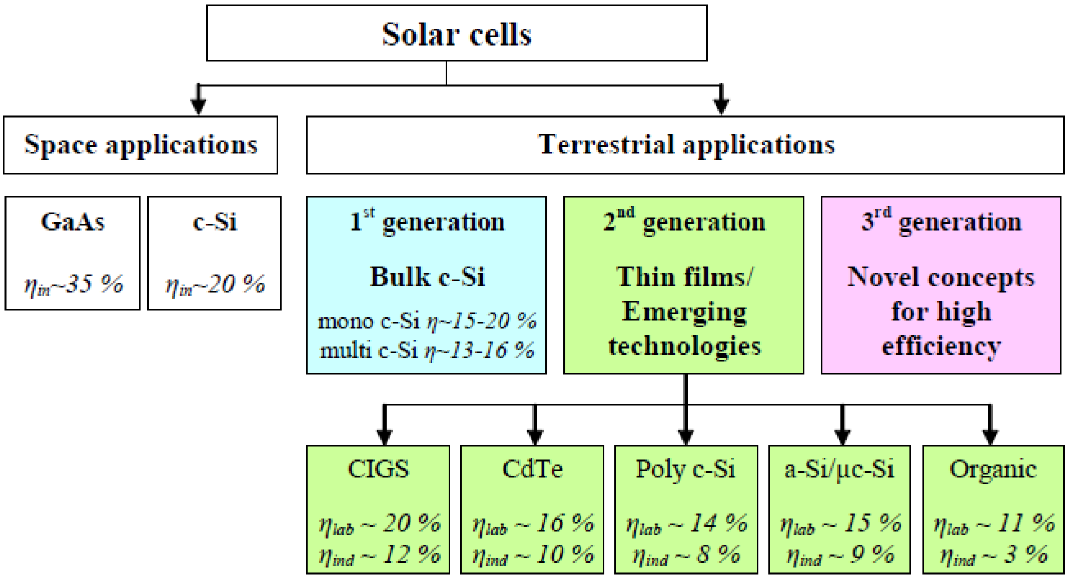


Figure 15: Overview of solar cell technologies used in different applications, [66]

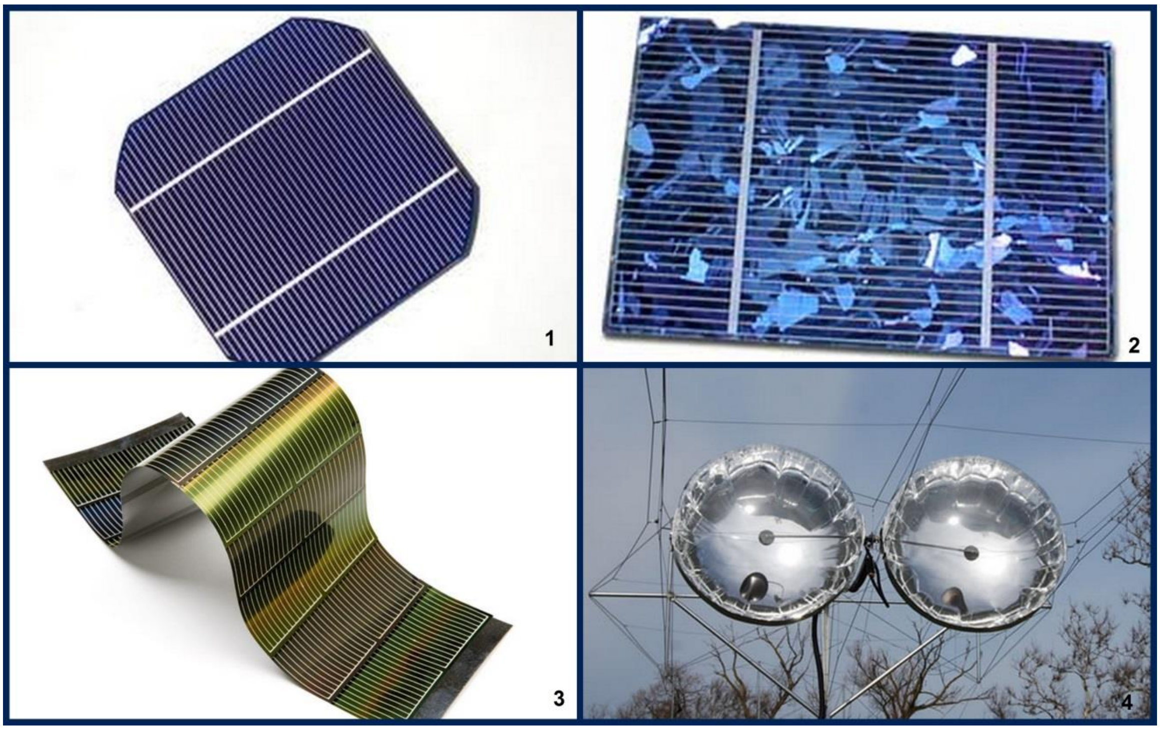


Figure 16: Examples of various types of solar cells. Pictures 1 & 2 represent the 1st generation (mono & poly c-Si respectively), picture 3 the 2nd generation (thin film a-Si) and picture 4 the 3rd generation (CPV) of solar cells

4.3 Description of Technology

4.3.1 Solar Cell: The cornerstone of PV Technology

Operation

The conversion of solar energy to electricity is realized by the solar cell, a semiconductor device able to deliver a certain amount of electrical power, characterized by an output voltage (V) and current (I). The main operating principle of all modern solar cells is based on the ***photovoltaic effect***. This effect is responsible for the generation of potential difference at the junction of two different materials in response to visible or other radiation. The basic processes of the photovoltaic effect are:

- First of all, the generation of charge carriers, particles free to move carrying an electric charge, due to the absorption of photons in the materials that form a junction,
- Next, the separation of the photo-generated charge carriers in the junction and
- Finally, the collection of the photo-generated charge carriers at the terminals of the junction, called the electrodes [66].

A solar cell structure consists mainly of the semiconductor material called the **absorber**, in which the photons of incident radiation are efficiently absorbed creating electron-hole pairs. As a material, a semiconductor has an electrical resistance in-between the one of a conductor (no resistance) and an insulator (infinite resistance). In such a material it is possible to add conductors, either positive or negative, in order to change its initial resistance. The negative conductors are **electrons** and the positive are **holes** that in fact represent the lack of electrons. One with more holes is called a p-type while one with more electrons is called an n-type semiconductor. However, the absorber is not charged, just doped with a number of current carriers, charges that are able to move free within the absorber's layer as they are not held tightly to their atoms. Though they can move to different locations, each of them is balanced out by a charge of the opposite type; thus the total charge of the absorber is neutral.

A solar cell comprises of both p-type and n-type semiconductors. By bringing them in contact with each other a **p-n junction** is formed allowing the flow of charges between them. The loosely held electrons and holes are attracted to each other resulting in the migration of some of the electrons into the p-type and some of the holes into the n-type material. As the charge of the material is changed by losing or gaining charged particles, an internal electric field is created. The region surrounding the junction is called **depletion region** and it is the one that gives the junction the ability to convert sunlight to electricity. There are various types of p-n junctions. Those formed by the same semiconductor material are called p-n homojunctions, while those formed by two chemically different semiconductors are called p-n heterojunctions. There are also other types such as the p-i-n junctions, in which the depletion region is enhanced by the use of an intrinsic, i, layer between the p-type and the n-type materials and the MS junction which is a junction of a metal and a semiconductor.

The production of electricity by a solar cell is triggered when placing the cell in the sun. Then, photons of light with sufficient energy strike the electrons in the p-n junction, excite them and as a result separate them from their atoms. The photons' energy should be of a specific range in order to achieve the transformation of solar energy to electricity. If the energy is not enough the electrons will not be "cut off" from the atoms and the holes will not move and if it is more than required, the excess of energy will be lost by heating up the cell. The free electrons that do not recombine with another atom before reaching the depletion region get swept to a higher potential through the internal electric field of the junction. Simply put, these electrons are attracted to the positive charge of the n-type and repelled by the negative charge of the p-type semiconductor. As they are pushed into the n-type silicon they repel each other due to the likeness of their charges. However, solar cells also consist of a top metallic grid or other electrical contact to collect electrons from the n-type semiconductor and transfer them to an external load (light or battery), and a back contact layer attached to the p-type semiconductor to complete the electrical circuit. This circuit provides an "escape path" for the colliding electrons, which move away from each other and create an electric current that travels through the circuit from the n-type to the p-type semiconductor. And this is how electricity is produced. A PV cell can still function even under cloudy conditions, as it uses not only direct but also diffuse solar radiation, which is light scattered by dust and water particles in the atmosphere. Apparently the amount of electricity produced in that case will be lower, as it is proportional to the intensity of sunlight falling on the cell.

Except for the semiconductors and the electrodes, solar cells also include special anti-reflecting coatings (ARC) in order to minimize the reflection of solar radiation on their surface. The coatings are similar to the ones used in other optical equipment, such as camera lenses, and consist of a thin layer of dielectric material with a specially chosen thickness [66], [63].

The following figures illustrate what we discussed in this sub-chapter. Figure 17 is a schematic illustration of a typical PV cell and figure 18 shows the process of converting solar energy to electricity.

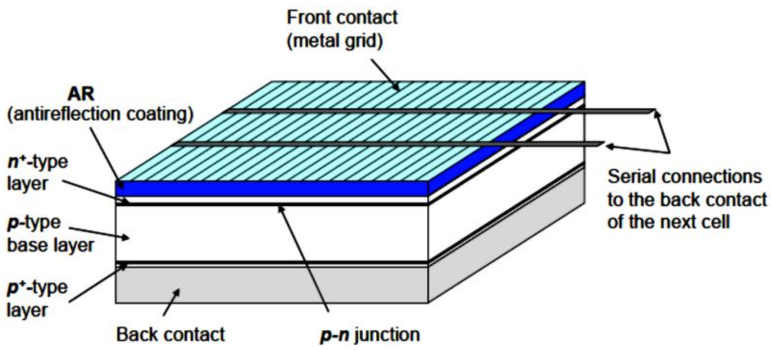


Figure 17: Schematic illustration of a typical solar cell, [66]

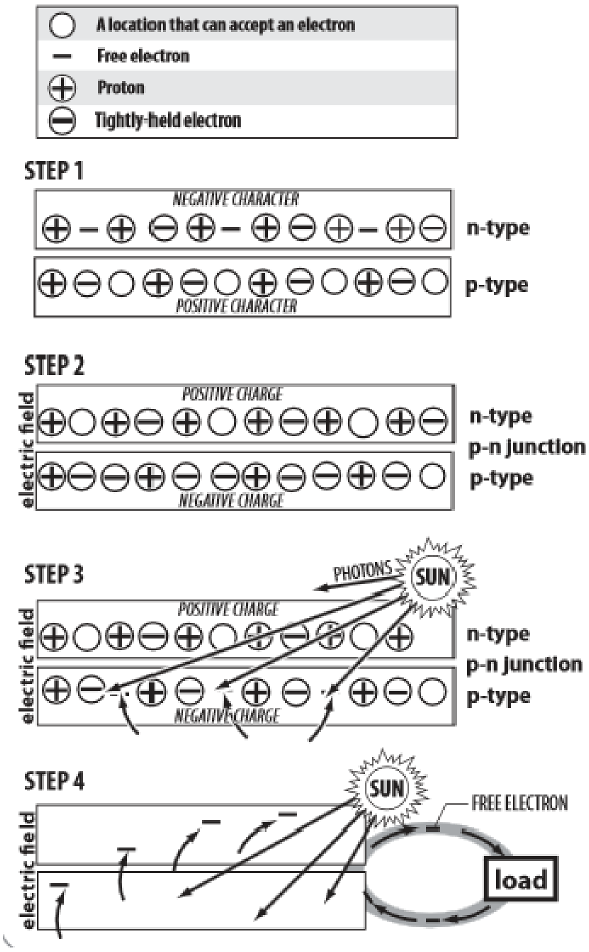


Figure 18: Process of converting solar energy to electricity, [63]

Performance

The performance of a solar cell is an essential parameter as it characterizes the efficiency of the energy conversion process. The **Current-Voltage Characteristics Curve**, shortly **I-V curve**, of a PV cell describes its energy conversion capability at the existing conditions of solar irradiance and temperature. Basically, the curve represents the combinations of current (I) and voltage (V) at which the cell can function, if the irradiance and cell temperature remain constant. An I-V curve is the result of measurements made by basic measuring tools, such as an ammeter and a voltage source or an instrument that combines both features. There is also one more graph evaluating the performance of a solar cell, called the **Power-Voltage Curve** (P-V curve), which can be derived from the I-V curve with the help of the equation $P = I \cdot V$. Figure 19 presents the typical I-V and P-V curves along with their key points:

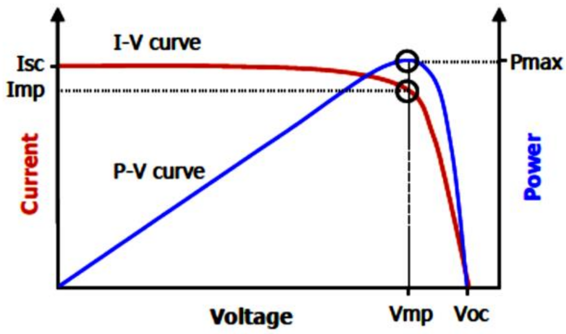


Figure 19: The I-V and P-V curves of a PV cell. The P-V curve is calculated from the measured I-V curve, [67]

In respect to figure 19, it can be seen that the span of the I-V curve extends from the **short-circuit current** (I_{sc}) at zero volts to zero current at the **open-circuit voltage** (V_{oc}). The first term refers to the current that flows through the external circuit when the electrodes of the solar cell are short circuited. The second term is the voltage at which no current flows through the external circuit. The values I_{mp} and V_{mp} represent the maximum power point of the curve, in other words the point at which the cell produces the maximum electrical power. Regarding the voltage, it is observed that at values lower than the V_{mp} the flow of the generated electrical current to the external load is almost independent from the output voltage, something that changes significantly near the "knee" of the curve. This happens due to the increasing recombination of the charge carriers occurring in the cells from this point and further. At V_{oc} all of the charge carriers inside the solar cell recombine.

Another important factor for the evaluation of the performance of a solar cell is the **fill factor** (FF). It is the ratio of the maximum power generated by a solar cell to the product of $V_{oc} * I_{sc}$ and is given by the equation: $FF = (I_{mp} \cdot V_{mp}) / (I_{sc} \cdot V_{oc})$. In fact, it compares a PV cell's I-V characteristics to those of an ideal cell. For an ideal solar cell, the fill factor is equal to 1 but in practice, due to the energy losses of the cells, it is always less. The importance of the fill factor is obvious in cases when the I-V curves of two or more individual PV cells have the same I_{sc} and V_{oc}. Under these circumstances, the one with the higher fill factor is able to produce more power. The magnitude of the fill factor depends strongly on the cell's technology and design. For example, a-Si cells show lower fill factors than c-Si cells.

Regarding the performance of a cell, the **conversion efficiency** (η) is also a factor that should be mentioned. It is the ratio of the generated maximum power of a cell to the incident solar power it receives and is calculated as: $\eta = P_{mp} / P_{in}$. The irradiance power, P_{in}, of 1000W/m^2 has become a standard for measuring the conversion efficiency of solar cells. The magnitude of conversion efficiencies depends again on the cell's technology and design. It usually ranges between 17% - 18% [66], [67], [68].

4.3.2 From Solar Cells to PV Systems

Description & Types of PV Systems

The amount of voltage and current produced by a single cell is insufficient almost for all electrical applications. Therefore, cells are connected together in series creating **strings**, in parallel or in a combination of both in an attempt to increase the PV-generated voltage and current. These interconnected cells and their electrical connections are then placed between a top layer of glass or clear plastic and a lower layer of plastic or plastic and metal. An outer frame is attached to them in order to enhance their mechanical strength but also to give the whole unit a way of mounting. The final product is called **module** or **panel** and it is the basic building block of PV systems. Similarly, and for the same reasons, groups of modules can be connected with each other in series and/or parallel forming an **array** [69]. Figure 20 displays the difference between solar cells, modules and arrays:

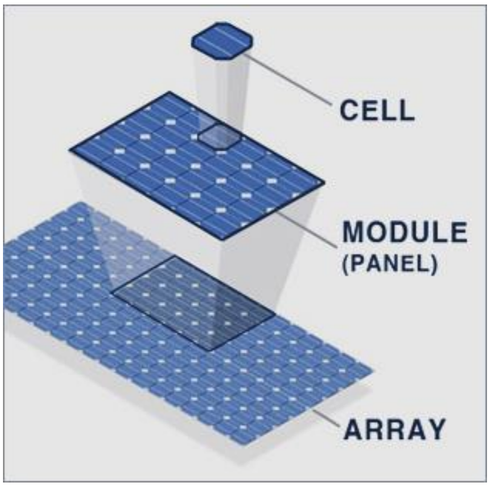


Figure 20: From solar cell to solar array, [70]

In general PV systems are divided into two main categories: the stand-alone and the grid-connected (grid-tied) systems. The systems belonging to the first classification operate independent of the utility grid, are self-sufficient and are designed to supply specific DC and/or

AC electrical loads. They could be powered by just a PV array or could be combined with wind turbines, engine-generators or the utility grid as an auxiliary power source, forming a PV-hybrid system. The systems of the second classification are connected to the utility grid and are designed to operate in parallel with it. Their main advantage is that power can be drawn from the utility grid but when the grid cannot provide it, the PV system can supplement it [71].

A complete PV system, except for the solar panels, typically consists of a number of components, altogether called the **balance of system** (BOS). The parts composing the BOS depend on the type of the system and are presented as follows:

- **Inverter**

  The main principle of function of an inverter is to convert DC electricity generated by the PV modules into AC and feed it into the corresponding loads – either appliances or the utility grid- at the required voltage, frequency and phase. They are available in a wide range of sizes and types, depending on the configuration they are going to be used. Some require transformers for regulating the voltage to proper levels but some others do not. However, it is important to point out that inverters suited for grid-tied systems are not the same as the ones suited for stand-alone systems. The first include additional operations such as the Maximum Power Point Tracking (MPPT) which tracks the point of the I-V curve of the array at which electrical power is maximized or the anti-islanding operation that ensures the non-hazardous function of the system by automatically disconnecting itself from the grid in cases of blackouts or other serious fluctuations in voltage and frequency. Thus an unexpected energizing of utility lines is prevented while workers are repairing or maintaining them. Similarly, stand-alone inverters have different characteristics as they have to be able to cooperate with energy storage systems such as batteries. Even in cases where stand-alone systems are simultaneously connected to the grid for energy backup, the corresponding inverters are different from the grid-connected ones as they can only take but not feed power into the grid [72], [73].

- **Transformer**

  Typical PV inverters produce output voltages lower than the ones managed by the utility grid at proper operation by a magnitude of tens or hundreds of thousands of volts. Thus, in grid-connected systems, step-up transformers are essential, as their function is to enhance the output voltages of the inverters and deliver it to the grid. The sizing of such a transformer is a crucial matter, as on one hand rated power higher than necessary can result in instabilities and economic disadvantages but on the other hand lower rated power could compromise the whole capability of the system. Transformers should be robust enough to operate under difficult weather conditions such as high summer temperatures and harsh winters. Usually, they last for 25-75 years and normally they do not require replacement during the life of a photovoltaic power station [74].

- **Batteries**

  In stand-alone systems there is always a mismatch between the generation of electricity and the actual demand, as the loads are operating not only during times with sufficient radiation but also during nights and periods of overcast weather. In order to overcome this problem special rechargeable batteries able to last long under conditions of daily charging and discharging, with good efficiencies at low-charging currents and low discharge-rates are essential. Such types of batteries are known as deep-cycle batteries and are practically rows of electrochemical cells connected in series with each other, forming a battery bank. The battery types used for energy storage in PV systems can be lead-acid, nickel-cadmium or nickel-iron batteries with the first type being almost invariably dominant as the other two are still very expensive and low efficient. Energy storage is usually not essential for grid-tied systems, though few of them may include it [72], [73].

- **Charge Controller**

  These devices are only parts of PV systems equipped with batteries and are responsible for protecting them and prolonging their lifetime without interfering with their efficiency. The main functions of a charge controller are to prevent the batteries from over-charging, over-discharging and from the current flowing into PV arrays at night, known as reverse current. Charge controllers vary in size and price. They may also perform other, more sophisticated operations as well, e.g. MPP tracking, but this directly means significantly higher costs [66], [72], [73].

- **PV combiner box**

  As already mentioned, several strings of cells are used in order to reach the desired operating voltage of the corresponding electrical loads. A PV combiner box is actually a box, necessary for the system, as it connects up in parallel all the cables coming from the cell strings and heading to the inverter. It also houses string fuses so that in case of a damaged DC string cable high currents can be prevented. Furthermore, surge/over-voltage protection is housed in the combiner box so that high voltages, e.g. induced by a lightning strike, cannot harm the installation [72], [73].

- **DC & AC disconnect/isolator**

  A PV array tends to produce voltage whenever it is exposed to solar radiation. The DC disconnect/isolator is a switch needed to disconnect the array from the inverter during installation, repair or maintenance. Especially in grid-connected systems, the AC disconnect/isolator is a similarly important switch responsible for disconnecting the inverter from the utility grid whenever the energy shouldn't be fed to the PV system [72], [73].

- **Circuit Breaker**

  A circuit breaker is a manually or automatically operated electrical switch designed to provide overcurrent protection to a stand-alone PV system. Circuit breakers offer fine-tuned adjustment and greater accuracy than the simple string fuses [75].

- **Utility Meter**

  The term "net-metering" refers to metering electricity sold to the grid and bought from it with the help of a single meter. This meter, installed to keep track of the power used and the power fed to the utility grid from a PV system, is called utility meter. Meters are usually installed and owned by the civil electricity company. However, specific metering requirements and options differ between countries and utilities. Several configurations are possible [73].

- **Cables**

  The wiring used in PV systems must have additional properties compared to the one used in normal electrical applications. To be precise, all the transmission cables should be double-insulated, UV and water-resistant, suited for high temperatures and high voltages, light and flexible to work with, flame resistant and low-toxic in cases of fire [73].

- **Mounting structures & equipment**

  A wide variety of mounting structures is actually available, with the ones fixed on top of roofs being the most dominant. Other systems incorporate the modules in the roof or in the building façade. There are also free-standing fixtures for the mounting of photovoltaics on the ground. Another mounting factor that can be adjusted is the inclination or tilt angle of the PV panels. The materials used to construct the mounting structures are aluminum, stainless or galvanized steel. Especially screws, nuts and bolts are only made of stainless steel in order to be resistant to early corrosion.

In figures 21 and 22 examples of typical stand-alone and grid-connected PV systems respectively are illustrated:

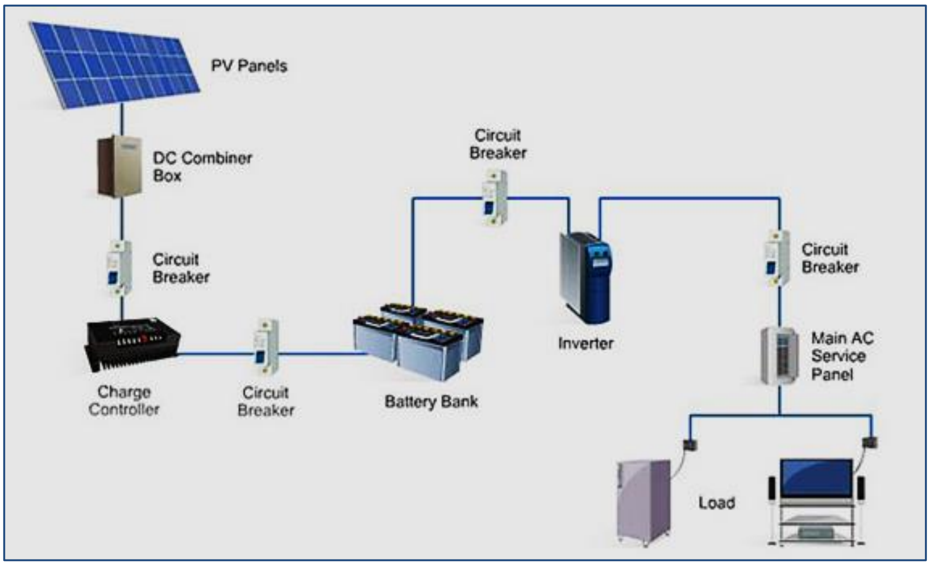


Figure 21: Stand-alone PV system powering AC loads with battery bank, [76]

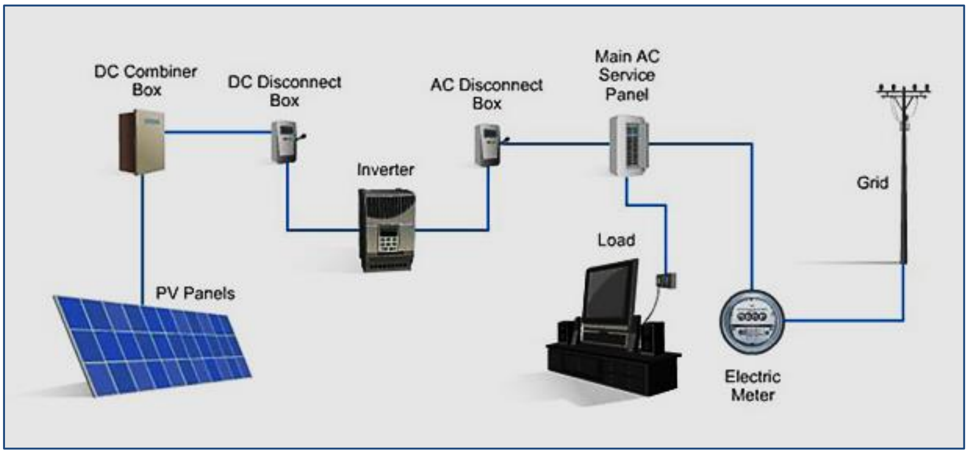


Figure 22: Grid-connected PV system powering AC loads, [76]

4.3.3 PV Power Stations

At the early stages of photovoltaics' development, PV systems represented exclusively decentralized power supply due to their limited capacity. As years passed by the technology advanced and the capacity of PV systems steadily increased allowing their use in many new fields. As a result, the installation of the first PV power stations, generating electricity on a large scale with nominal power up to 1 MWp, was achieved. PV power stations are different from most building-mounted and other decentralized solar applications as they are intended to supply power at the utility grid, rather than to a local user or users. They can be grid-tied as well as stand-alone systems. The first type is encountered where the site of implementation has connecting access to the central utility grid, while the second type is found where the implementation site cannot interconnect with the main land's grid and consequently there is the need of building up an independent electricity generation network. A perfect example are islands, where the PV power plants constructed are usually stand-alone or hybrid PV systems combined with wind turbines, diesel-generators or other energy producing technologies [77].

4.3.3.1 Technology

Regarding the setting of a PV plant, most of them use ground-mounted arrays, also called free-field or stand-alone. The configuration of those arrays can be fixed-tilt or tracking and in the case of tracking it can be either single or dual axis. Comparing to the fixed-tilt, the tracking configuration improves the total energy performance but also increases the installation and maintenance costs of the PV system. Short descriptions of the above mentioned mounting structures follow:

Fixed-tilt arrays

This configuration consists of PV panels mounted at a fixed inclination calculated to provide the optimum annual energy output. Normally, the modules are oriented towards the Equator, at a tilt angle slightly less than the latitude of the site. However, there are some cases where different tilt angles are used, depending on local climatic, topographical or electricity pricing regimes. A variation of this configuration is the use of arrays, whose tilt angle can be adjusted twice or four times a year. As a result, the system has better seasonal performance but requires more land area in order to avoid the internal shading of the modules at the steeper winter tilt angle [78], [79].

Tracking arrays

Solar trackers are devices used for orienting solar panels in a vertical position towards the sun. Thus, the intensity of incoming direct radiation on the panels is maximized and the amount of power produced by the PV system is enhanced. Arrays can be designed using single or dual-axis trackers. However, tracking systems are only worth installing in regions with mostly direct sunlight, as in cases of diffuse light (cloudy or foggy conditions), tracking has no actual value.

- **Single-axis trackers**

  This kind of trackers follows the sun in one dimension; along its route across the sky over the course of the day. The angle of the axis is normally horizontal, though some incline the axis towards the equator in a north-south orientation. The most important benefit of single-axis trackers is that they achieve more efficient solar energy production compared to a fixed tilt system by approximately 10%-25% with a relatively small penalty in terms of land area, capital and operating cost [80], [81].

- **Dual-axis trackers**

  Dual-axis trackers are capable of following the path of sun in two dimensions; in its daily orbit across the sky and as its elevation changes throughout the year. The increased energy output of the system can be up to 30% in locations with high levels of direct radiation but the raise is limited in temperate climates or those with more significant diffuse radiation. One of the downsides of dual-tracking is the large land area needed in order to avoid the phenomenon of inter-shading between the modules as the sun moves and the arrays' orientation changes. Moreover, dual-axis trackers require more complex mechanisms to maintain the array surface at the required angle leading to higher capital and maintenance costs [78], [79].

4.3.3.2 Performance

The evaluation of the performance of a large-scale solar park is based on the following indicators:

- **Final Yield (Y_f)**

  The final yield is defined as the annual, monthly or daily net energy output (E) of a PV park divided by the peak power (P_{rated}) of the installed array at standard test conditions (STC) of 1000 W/m^2 solar irradiance and 25°C cell temperature. The final yield normalizes the energy produced with respect to the system size, which makes it a convenient indicator to compare the energy produced by PV systems of different sizes. Its units are hours or kWh/kW, with the latter being preferred as it describes the exact quantities from which the parameter derives [82], [83]:

  $$Y_f = \frac{E}{P_{rated}} \quad \text{[kWh/kW] or [hours]}$$

- **Reference Yield (Y_r)**

  The reference yield (Y_r) is the total in-plane solar insolation H_t (kWh/m^2) divided by the array reference irradiance G (1 kW/m^2). It represents the number of peak sun-hours and it defines the solar radiation resource for the PV system. It depends on the location, orientation of the PV array, and month-to-month or year-to-year weather variability [83], [82]:

  $$Y_r = \frac{H_t}{G} \quad \text{[kWh/kW] or [hours]}$$

- **Performance Ratio (PR)**

  The performance ratio (PR) is defined as the final yield divided by the reference yield. This indicator is one of the most important ones for evaluating the efficiency of a PV plant and represents the total losses in a PV system when converting from nameplate DC rating to AC output. The typical losses of a PV park are caused by panel degradation ($\eta_{\deg}$), temperature (η_{tem}), soiling (η_{soil}), internal wiring network (η_{net}), inverter (η_{inv}), transformers (η_{tr}) and system availability and grid connection network (η_{grid}). The performance ratio is mainly used to compare the efficiency of grid-connected PV plants at different locations and with various types of modules. It is calculated once per month or once per year but it can also be calculated in smaller time intervals, weekly or daily, in order to identify component failures. Over the years of a system's operation, decreasing annual PR values may indicate a permanent loss in its performance [82]. Depending on geographical location and season, the PR values are usually within the range of 20% to 80% [84]. However, identical PR values for new-designed PV plants are between 80%-90% [85]. The equation giving the performance ratio is the following:

$$PR = \frac{Y_f}{Y_r} = \eta_{\deg} \cdot \eta_{tem} \cdot \eta_{soil} \cdot \eta_{net} \cdot \eta_{inv} \cdot \eta_{tr} \cdot \eta_{grid}$$

- **Capacity Factor (CF)**

  The capacity factor (CF) is one more indicator of the performance and quality of a PV park, defined as the ratio of the actual annual energy output of the park to the amount of energy it would generate, if it operated at full rated power (P_{rated}) for 24h per day for a year (8760 hours) [83]. The CF values vary significantly for solar PV systems as they highly depend on the location. Generally, they are in the range of 10-25%. The capacity factor is given by the following equation:

$$CF = \frac{E}{P_{rated} \cdot 8760} = \frac{Y_f}{8760} = \frac{H_t \cdot PR}{P_{rated} \cdot 8760}$$

4.4 PV Power Stations in Greece

4.4.1 Past, present and future state

Numerous long-term measurements have proven that Greece is one of Europe's sunnier regions and consequently it holds an excellent solar energy potential. More precisely, the country is situated in the South-East Mediterranean area and possesses an abundant and reliable supply of solar energy, even during wintertime. The entire territory has high solar irradiance which in terms of annual solar energy at a horizontal plane is measured to be between 1450 kWh/m^2 - 1800 kWh/m^2. Figure 23 illustrates the global solar irradiation and solar electricity potential in Greece. According to this figure, it can be seen that the Southern part of the country, and especially the Aegean Archipelago islands, receive the highest values of solar irradiation, while the Northern part is less favored [86].

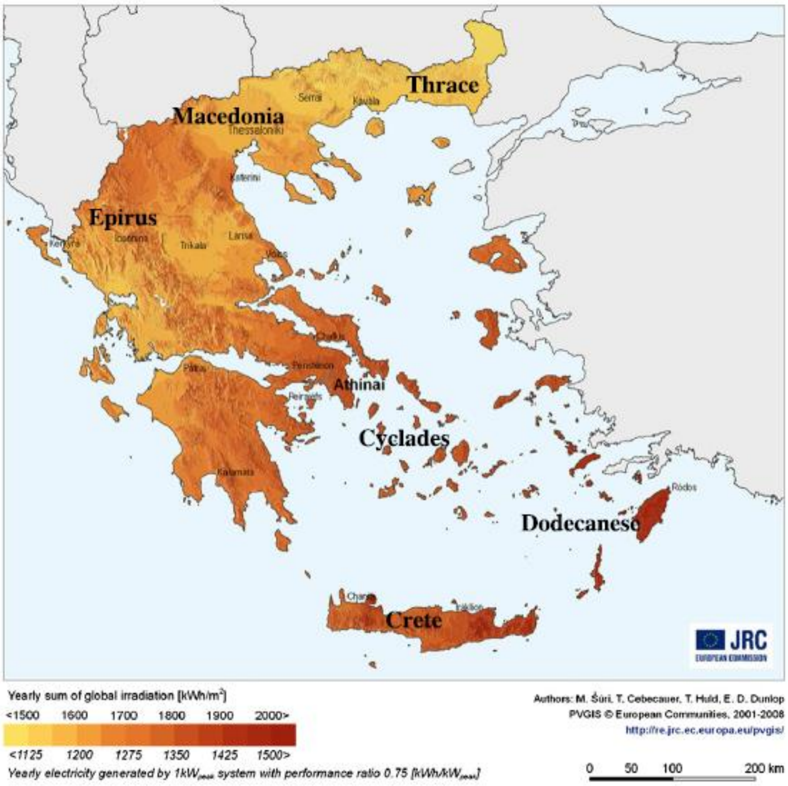


Figure 23: Global solar radiation in Greece, [86]

The electricity network of Greece consists of two parts; firstly, of the mainland's national grid, primarily based on centralized thermal power plants using lignite as a fuel, and secondly of many autonomous power stations using diesel-generators to accommodate consumers inhabiting the small and medium-sized islands or other remote regions. The photovoltaic power stations in Greece include all the ground-mounted PV systems that are connected to the mainland's utility grid as well as the ones installed on the non-interconnected regions for autonomous energy supply.

In Greece photovoltaic technology emerged nearly ten years ago. Since then, many attempts have been made to take advantage of solar power and the corresponding technology on national level. The Greek PV market, including all types of PV systems, grew from 2MWp total installed capacity in 2007 to 2627MWp in 2013. This is shown in figure 24, where both the annual and total installed PV capacity in Greece from 2007 till 2013 is depicted.

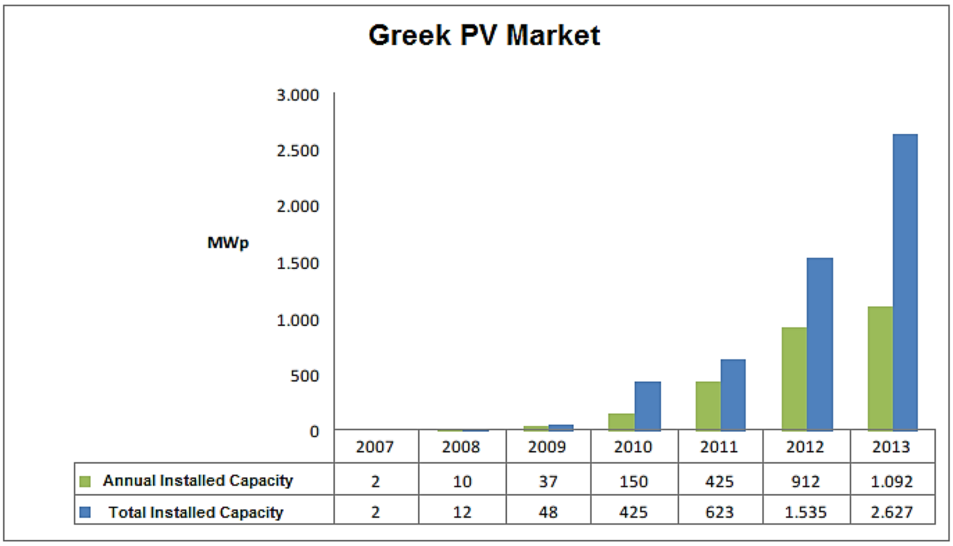


Figure 24: The development of the Greek PV market in terms of annual and total installed capacity 2007-2013 (last updated on November 2013), [87]

More specifically, the status of development relating to the PV power stations in Greece is illustrated in figure 25. The detailed graph shows that on November 2011 the total installed capacity of PV stations was 400MWp, while on November of 2013 it reached the 2070MWp. The difference between the 2627MWp of total PV capacity and the 2070MWp of PV stations' capacity is covered by the installed capacity of roof-mounted PV systems, either for residential or for commercial use.

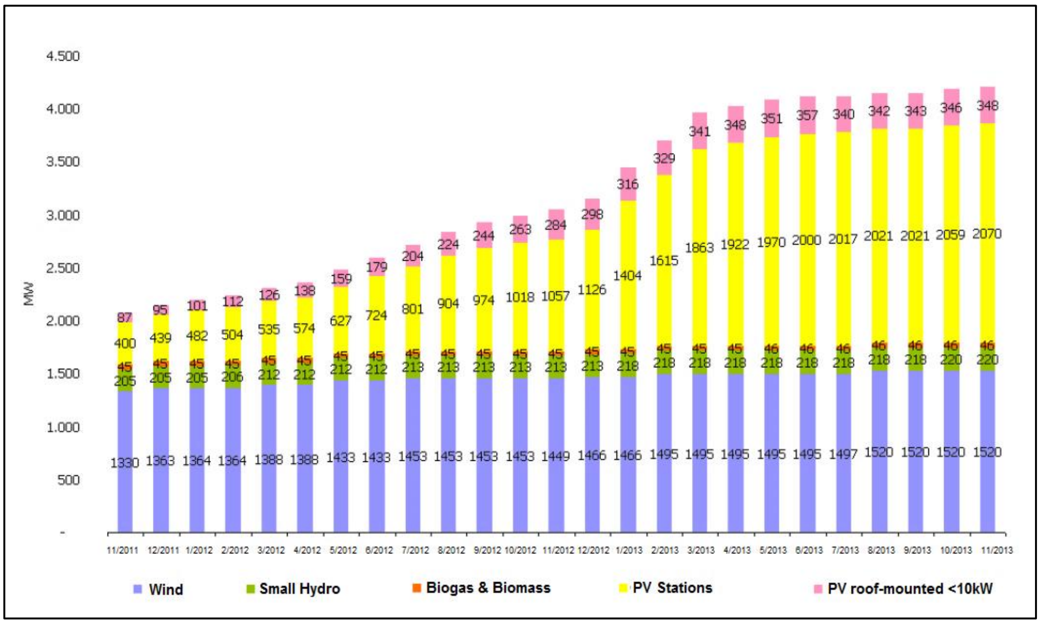


Figure 25: Total Installed Capacity (MWp) of RES units connected to the Greek utility grid in the period 2011-2013, [88]

The dispersion of PV power stations throughout Greece can be seen in figure 26, which was made with the help of an interactive internet platform developed by the Greek Regulatory Authority for Energy. This special software is in fact a geographic map that gives the user the opportunity to locate the exact position of wind farms, biomass fields, photovoltaic plants, hydropower stations etc. in the Greek territory and retrieve additional information about them.

Figure 26: Dispersion of PV power stations in the Greek territory, [89]

As far as the future is concerned, Greece is committed to the regulations of the European Commission's Renewable Energy Directive 2009/28/EC and the national Law 3851/2010, regarding the penetration of RES in the country's electricity production. As already mentioned in chapter 3, the National Renewable Energy Action Plan (NREAP) imposes 20% production of the final energy consumption and 40% electricity generation coming from RES by 2020. Specifically, for the PV technology, three different economic recovery schemes are proposed and impose a total installed capacity of solar PV of 0.7GW (Reference scenario), 2.2GW (Compliance scenario) and 2.9 (Accelerated scenario) by 2020 respectively. It is obvious that the growth of the technology was so quick and wide that two out of the three scenarios have already been fulfilled seven years earlier than predicted.

Furthermore, a project called "HELIOS" is introduced by the Greek government and its primary objective is the installation of PV power stations on Greek land and subsequently the export of the produced energy to countries of Northern Europe (mainly Germany). The profits of the exports are intended to be used for paying back part of the country's public debt. The duration of the project is planned to be four years; in the first year 2GW of PV are going to be installed, in the second 4GW, in the third 7GW and in the fourth 10GW. The project was originally considered in 2012 but little progress has been made since then [90], [91].

Despite the rapid growth of the Greek PV sector during the last decade, the future development of the technology in general and of the PV power stations in particular is jeopardized as the market is going through a serious standstill. Unfortunately, there are several reasons behind the current recessive situation. Firstly, the Operator of Electricity Market, responsible for regulating the general function of the electricity market in Greece, shows serious deficits. The crisis has taken its toll, as from mid-2012 significant reductions in the guaranteed selling prices of electricity (FITs) produced by RES have occurred, along with the total abolition of photovoltaic subsidies, which used to ease such investments. In addition, a temporary tax, ranging between 25% and 42%, has been imposed to all operating PV plants, hindering even more investments on this sector. Lastly, a regulation that influences a lot the future of the technology is the freezing of the licensing procedure for new PV power stations, imposed in August 2012 and confirmed in May 2013 [92].

4.4.2 Licensing Procedure

The implementation of RES in the Greek electricity production was promoted in 2006 by the national Law 3468/2006, for the first time as a priority with specific rules and principles. In June 2009, a joint Ministerial Decision, issued under the authority of the same Law, established a special development program for Photovoltaics and opened the way for the installation of small PV systems on buildings. Till then, the licensing procedure of new renewable energy projects in general and PV stations in particular was long and complicated, deterring the majority of potential investors. One year later, the Law 3851/2010, except for setting the national targets for RES by 2020, made a significant effort to simplify and shorten the process of approval for such projects by aligning certain lengthy individual steps and eliminating others. However, in some cases complying with the deadlines for the final licensing of a project is still not achieved. Much need to be done, especially in the field of non-energy legislation (use of land, environmental legislation, etc.) [93].

Especially for the PV power stations in Greece, the whole procedure needed to be undertaken by new investors in order to obtain all the necessary licenses and be able to build and run a new solar park is presented step by step as follows [92], [94], [95]:

Step 1:

Production License

The first step towards the licensing of a PV power station is the application for the production license, issued by the national Regulatory Authority for Energy (RAE). After examining the satisfaction of certain criteria implied by law, RAE proceeds to the issuance or not of the production license within 2 months from the submission date of a complete application folder. This license is valid for up to 25 years and can be renewed for an equal period of 25 years. In cases where the installation license, which will be explained later, is not issued within 30 months of the issuance of the production license, the latter is being automatically retracted. According to the provisions of Law 3851/2010, a production license or any other declaration, known as 'exception', is no longer required for PV systems with installed capacity of up to 1MWp.

Step 2:

Offer for Connection to the System or the Grid

Approval of Environmental Conditions (AEC)

Permission for intervention in a forest or a forest area

After the first step is completed, the potential investor should apply simultaneously for:

- a Connection Offer from the authorized Manager of the System or the Grid,
- a Decision of Approval of Environmental Conditions (AEC) and
- a Permission for intervention in a forest or a forest area or generally in the site of installation of the project.

The Connection Offer is issued by the authorized Manager within 4 months and it becomes definite and binding when the AEC decision for the PV station is also published. The latter is issued within 4 months and after the corresponding authority has carefully examined the environmental impacts and the proposed mitigation measures of the project. The AEC decision lasts for 10 years and can be renewed twice for the same period of time. It is not required for PV systems up to 500kWp, as long as they are not to be installed in NATURA areas, coastal areas and in regions close to another operating PV plant with such installed capacity that the total energy output would exceed 500kWp. However, a certificate from the relevant environmental authority of the region, confirming that the PV station is exempt from the AEC obligation, is necessary. The Connection Offer remains valid for 4 years from its finalization.

Step 3:

Grid Connection Agreement and Power Purchase Agreement

Installation License

Building License

After the Connection Offer is finalized, the applicant may continue with the next step of the licensing procedure, which is the execution of the Grid Connection Agreement and Power Purchase Agreement with the Transmission Grid System Operator or the Public Power Company.

At the same time, the applicant can proceed with the acquisition of the installation license. This license is issued by the General Secretary of the Region within 15 working days from the completion of examining the relevant documentation. It is valid for 2 years and can be extended for another 2 years at the most. PV stations with installed capacity up to 1MWp are released from the requirement of such a license.

After the installation license is granted, a Building License is issued by the City Department of Urban Planning in order to obtain permission to proceed with minor scale-interventions before the final installation of the PV system.

Step 4:

Operation License

The final step of the licensing procedure consists of the acquisition of the operation license. This license is granted from the same authority that is responsible for the granting of the installation license and is valid for 20 years. It is given after construction and trial-operation of the plant and after the Center for Renewable Energy Sources (CRES) approves the whole operation. It is issued within a strict deadline of 20 days from the completion of the above inspections, in line with the Minister of Environment, Energy and Climate Change. Once again, PV stations with installed capacity of up to 1MWp are exempt from the requirement of an Operation License.

As there are slight differences in the licensing procedure followed by PV power plants of different installed capacities, table 8 summarizes the steps for each category:

Table 8: Licensing Procedure for PV power stations of different installed capacities in Greece, [92]

Steps	PV Power Stations by Installed Capacity		
	≤ 500 kWp	500 – 1000 kWp	≥ 1000 kWp
1	-	-	Production License
2	Connection Offer Certificate of exemption from AEC	Connection Offer AEC	Connection Offer AEC
3	Grid connection/Power Purchase Agr. Building License	Grid connection/Power Purchase Agr. Building License	Grid connection/Power Purchase Agr. Installation License Building License
4	-	-	Operation License
5	Installation of PV Station	Installation of PV Station	Installation of PV Station

4.4.3 Stakeholders

In this sub-chapter the stakeholders taking part in the photovoltaic sector in Greece are presented. Their general responsibilities, interconnections and special functions relating to PV projects are analyzed. These stakeholders can be classified into the following groups: Policy Makers, Authorities, Independent Authorities, Business, Associations, Research, Non-Governmental Organizations and Technology Users. A stakeholder's map illustrating the interactions between them can be seen in figure 27.

POLICY MAKERS

In this group both the **European Union** and the **Greek Government** belong. The former poses the directives, goals and support regarding PV projects in Europe, while the latter sets the corresponding policies and provides the necessary support schemes so that these goals can be realized in Greece.

AUTHORITIES

Ministry of Environment, Energy and Climate Change (MEECC)

As already mentioned in chapter 3, MEECC is the central institution in climate and energy policy making in Greece. As a PV stakeholder, it is responsible for the development of RES policies as well as for the integration of the corresponding EU Directives into the Greek Legislation. It also oversees the Centre for Renewable Energy Sources and Saving (CRES), co-operates with the Regulatory Authority for Energy (RAE) and supervises the majority of shareholder functions of the Public Power Corporation (PPC) and the Hellenic Transmission System Operator (HTSO) [29].

Municipal, prefectural & regional authorities

As PV stakeholders, the regional and local authorities are also involved in the provision of installation and operation licenses, as well as environmental permits.

Operator of Electricity Market (OEM)

The Operator of Electricity Market was introduced in chapter 3, but as far as renewable energy is concerned the institution is responsible for making the contracts for the sale of electricity produced by RES plants, for providing priority dispatch and for pricing the electricity produced by RES [54].

INDEPENDENT AUTHORITY

Regulatory Authority for Energy (RAE)

The Regulatory Authority for Energy (RAE) is a financially and administratively independent public authority, as already stated in chapter 3. Its main duties as a renewable energy stakeholder are the monitoring of the operation of the energy market and the licensing of RES projects for electricity generation. As mentioned previously, RAE is responsible for the granting of the production license of a RES plant based on specific technical and economic criteria. The collection and processing of information from energy companies, as well as the participation in the pre-parliamentary legislative process of measures related to compliance with competition rules and to the overall protection of the consumers in the energy market are also within the competencies of the agency. Lastly, RAE gives its advice on tariff-setting [52].

BUSINESS

Public Power Corporation (PPC) S.A & PPC Renewables S.A.

The Public Power Corporation (PPC) is the biggest power producing and electricity supplying company in Greece. In the renewable energy sector, it operates through its subsidiary company, PPC Renewables S. A. (PPCR), which as far as photovoltaics are concerned has already installed 6 PV stations with a total capacity of 0.7MWp all over the country. In the future, PPCR plans to develop more PV parks of even larger-scale, totaling to an additional power of 260.84MWp [96].

Private Solar Energy Producers, Manufacturers & Suppliers

The private stakeholders taking part in the PV sector of Greece can be divided into solar PV producers, manufacturers and suppliers. Their interconnections are obvious, as the producers are depending on manufacturers and suppliers of the technology in order to make their investment viable and efficient. According to the professional archives of the Centre for Renewable Energy Sources and Saving (CRES), 298 companies are currently involved in the Greek PV sector, occupied with various activities covering every aspect of a PV system [97].

ASSOCIATIONS

Hellenic Association of Photovoltaic Companies (HELAPCO)

HELAPCO was established in 2002 and it is a non-profit organization, representing the major PV companies active in the production, trading, installation and maintenance of photovoltaic systems in Greece. HELAPCO represents the domestic market in international meetings and fora, and is a member of the European Photovoltaic Industry Association (EPIA). Currently, the association counts 56 officially registered members [98].

Greek Association of RES Electricity Producers (GAREP)

The Greek Association of RES Electricity Producers (GAREP) was founded in March 1997 and it is a private, non-profit organization with more than 60 companies-members involved in the RES sector, whose objectives are the construction and operation of commercial RES installations. As a RES stakeholder, GAREP has the obligation to [99]:

- Represent its members before the Greek and international authorities or similar organizations and help in the building up of a network between them. In Greece, the association cooperates with various organizations and authorities, such as the Public Power Corporation (PPC), the Center for Renewable Energy Sources (CRES), the Regulatory Authority for Energy (RAE), the Hellenic Transmission System Operator (HTSO) and the Ministry of Environment, Energy and Climate Change (MEECC).
- Participate in the preparation for the drafting of laws and regulations that are relevant to RES.
- Contribute in the development of contacts between its members and the Greek and international Banking and Insurance System.
- Organize seminars, conventions, symposiums and other events for the promotion of RES in the electricity production.

Hellenic Association of Photovoltaic Energy Producers (SPEF)

The Hellenic Association of Photovoltaic Energy Producers (SPEF) was founded in March 2009 and it is both a scientific and a business association. The prerequisite to become a member is to have grid-connected a PV plant; thus all of its members are companies that own operating PV parks. Currently, the association has 435 members with a cumulative installed capacity of 314.45MWp. According to its statute, SPEF aims to [100]:

- Promote financial and legal issues and to support the economic and professional interests of PV producers.
- Study problems related to the production of energy from PV plants.
- Guide its members through procedures relating to the authorization and operation of PV parks.
- Represent its members to the Government, the international authorities and the media.
- Support initiatives for the protection of the environment.

Hellenic Association of Photovoltaic Investors (PASYF)

The Hellenic Association of Photovoltaic Investors (PASYF) was founded in 2008 and it represents investors holding an authorized energy production license from a PV system throughout the Greek territory. Its main purpose is to promote the installation of photovoltaics and to address issues that may concern them [101].

Invest in Greece S.A.

Invest in Greece S.A. is the official investment promotion agency of Greece. It operates under the supervision of the Ministry for Development and Competitiveness and its objective is to promote and facilitate private investment. As far as RES are concerned, the agency deals with wind, solar, geothermal and biomass energy and it provides investors with all relevant information about the investment environment, the current legislation and the licensing procedures. It also gives feedback to the Ministry for Development and Competitiveness, concerning the improvement of the legislative and administrative environment in order to boost new RES investments [102].

Hellenic Federation of Enterprises (SEV)

The Hellenic Federation of Enterprises (SEV) is a forum for modern enterprises in most branches and sectors of today's Greek economy. In the context of sustainable development, SEV has undertaken the following important actions [103]:

- Formed the SEV Council for Sustainable Development, a non-profit organization founded in 2008 by 31 Greek companies-members of the association. The Council's objective is to promote sustainable development in the Greek business reality and to create the necessary framework for discussing and weighing the critical issues of this matter between the State, businesses and society.
- Operates the "Sustainable Development Unit", a unit focused exclusively on sustainable development, responsible for monitoring issues related to the environment on both national and international level. At the same time, the Unit promotes the environmental strategy and policy of SEV to society through targeted actions but also through participation in collective bodies in Greek and international arena. Finally, it provides advice and organizes seminars on environmental policy issues.

RESEARCH

General Secretariat for Research & Technology (GSRT)

The General Secretariat for Research and Technology (GSRT) of the Ministry of Education, Lifelong Learning and Religious Affairs is the main public body for the administration of the Greek R&D system. Its main goals are to [104]:

- Establish institutes and technological centers in areas of high priority for the development of the Greek economy.
- Enhance research activities in the essential fields of the Greek economy by supervising and financing the best known and most important research and technological centers of the country.
- Support the transfer and diffusion of advanced technologies to the manufacturing organizations of the country as well as promote cooperation with other international organizations.
- Represent the country to the corresponding bodies of the European Union, aligning R&D activities with the demands of the European community.
- Maintain awareness of Greek society in science and technology, thus improving the lives of the citizens.

Centre for Renewable Energy Sources & Saving (CRES)

As already presented in chapter 3, the Centre for Renewable Energy Sources and Saving (CRES) is the national coordination center for Renewable Energy Sources (RES), Rational Use of Energy (RUE) and Energy Saving (ES). The organization was founded in 1987 and it is a public entity under the Ministry of Environment, Energy and Climate Change, financially and administratively independent. It is managed by a seven-member Administrative Council, with representatives from the General Secretariat of Research and Technology, the Public Power Corporation and the Hellenic Federation of Enterprises. As a stakeholder, CRES is the official consultant of the Greek government on matters of RES/RUE/ES in national policy, strategy and planning. It is responsible for carrying out applied research, for developing technologies which are both technically/economically viable and environment-friendly, for demonstrating and piloting such projects and for supporting the above technologies by providing expertise and information to interested third parties. The center also has the capability to implement such applications in private sector energy projects, local authorities and professional associations. Last but not least, it organizes and participates in technical seminars, scientific meetings, educational programs and specialized training courses. With respect to photovoltaics, CRES owns a PV Laboratory that includes [56]:

- An electronics laboratory
- A solar radiation measurements laboratory
- A battery laboratory
- A photovoltaic frames testing laboratory

The PV Laboratory is used for testing various battery types and technologies based on international standards, for measuring and controlling PV systems and electric vehicles and for testing PV frames and power electronic devices [105].

Centre for Research & Technology Hellas (CERTH)

The Centre for Research and Technology Hellas (CERTH) was founded in March 2000 and it is a non-profit organization, operating under the supervision of the General Secretariat for Research and Technology (GSRT). As the largest research center in Northern Greece, CERTH is active in several fields including alternative energy sources. Among its duties, the center conducts high-quality research, works closely with business to develop innovative solutions, cooperates with other academic and research institutions and trains young scientists in order to boost knowledge transfer [106].

Institute of Environmental Research & Sustainable Development (IERSD)

The Institute of Environmental Research and Sustainable Development (IERSD) is one of the five institutes that constitute the National Observatory of Athens (NOA), the oldest research center in Greece. Its target is to promote environmental science and engineering. It is particularly active in solar and wind energy, energy planning and energy conservation [107].

Universities

The technological universities of Greece play an important role as stakeholders of RES technologies. Their main objectives are to train young scientists, promote knowledge transfer and conduct academic research in cooperation with other institutions or businesses. Among universities, the National Technical University of Athens (NTUA), founded in 1836, is the oldest and most distinguished educational institution of Greece in the technological field. Regarding RES, NTUA has included them in its educational guide through post-graduate and master courses, experimental researches in laboratories and other relevant projects [108].

NON-GOVERNMENTAL ORGANIZATION

Greenpeace

The Greenpeace is an international non-profit organization that with its actions highlights the major environmental problems and promotes effective solutions for a green future. Stressing out the disastrous consequences of the use of conventional fuels for people, environment, economy and development, the Greenpeace is putting pressure on the Greek government to adopt and apply the roadmap for 100 % clean energy and energy savings by 2050 [109].

TECHNOLOGY USERS

The technology users are the Greek people in general that end up using the electricity produced by RES. This category consists of households, public services, enterprises and industry.

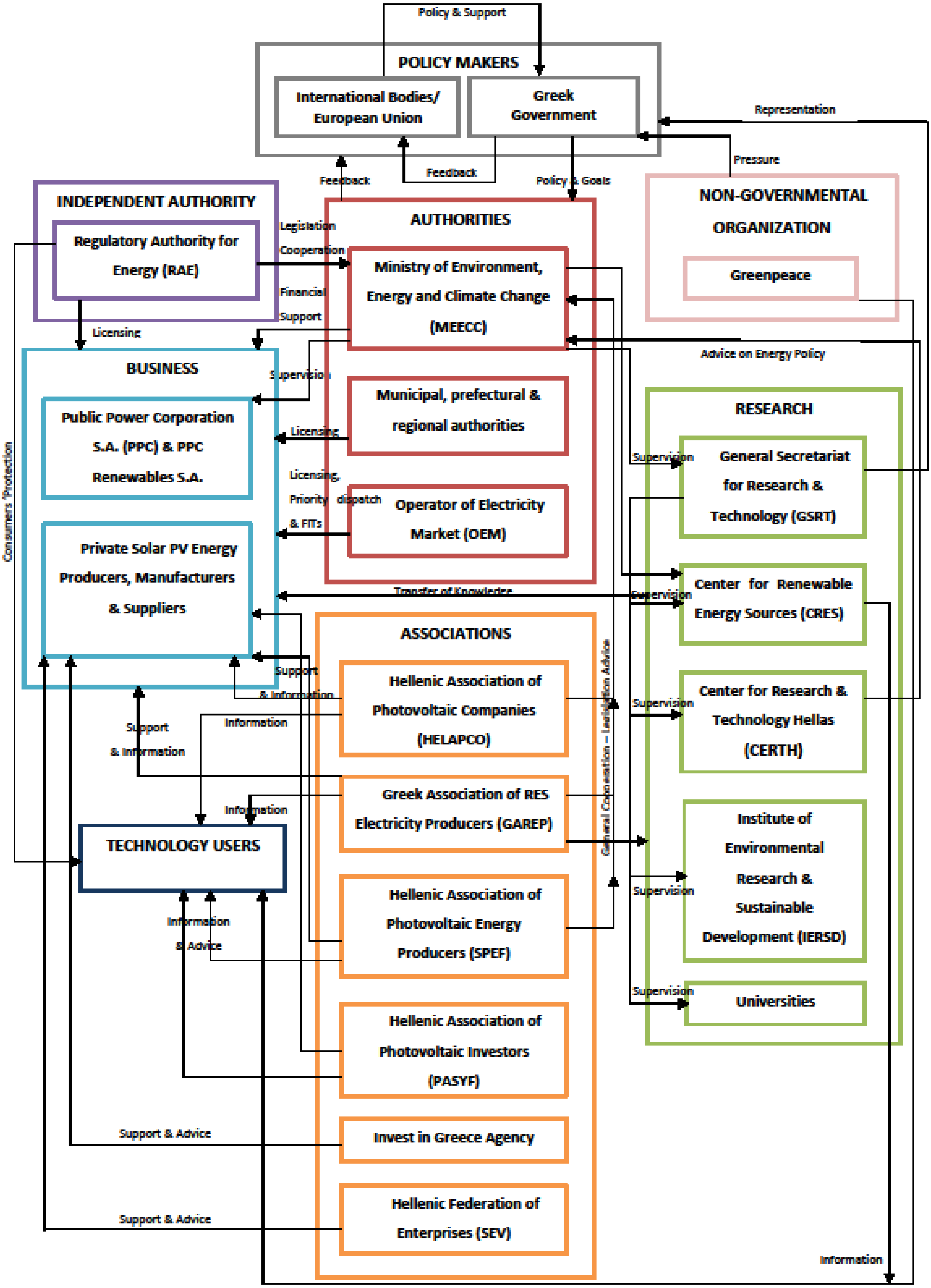


Figure 27: PV Technology in Greece – Stakeholders' Map

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Chapter 5: The Method of Social Cost-Benefit Analysis (SCBA)

The objective of the present thesis is to evaluate the transition of large-scale PV power plants in Greece during the recent economic crisis. This will be achieved with the conduction of a Social Cost Benefit Analysis (SCBA). The latter term refers to a feasibility study that investigates the viability of a policy or project from the society's point of view. In other words, a SCBA aggregates all the costs and benefits that derive from a proposed policy or project and determines whether its implementation can improve the welfare of society as a whole or not [110].

The current chapter attempts to familiarize the Reader with the general concept of SCBA before the thesis moves on to the practical application of the method. Firstly, the chapter presents a brief history of SCBA. Secondly, it introduces the main rationale of the method and it distinguishes the basic types of this kind of analysis. Thereafter, it analyzes in greater detail the distinct steps a SCBA analyst should follow. Then, it studies the conceptual foundations of SCBA and it evaluates the costs and benefits from the viewpoint of society. A reference to the factors that limit the application of SCBA is included as well. Subsequently, the chapter discusses the application of SCBA on renewable energy projects. The attention is drawn to solar energy and the costs and benefits of such projects, as far as two different receivers are concerned: the private investor and the society as a whole. The chapter ends with a thorough study of both categories for the specific case of Greece.

5.1 Theoretical Application of SCBA to General Projects

5.1.1 History of SCBA

The history of social cost-benefit analysis dates back to 1808, when Albert Gallatin, the US Secretary of the Treasury, gave the first recommendation for the use of such a method in public decision-making, by suggesting that the costs and benefits of water-related projects should be identified and compared. In 1936, the US Flood Control Act employed SCBA for the first time in flood control and harbor deepening projects. In 1950, the US Federal Inter-Agency River Basin Committee published a guide to SCBA, known as the Green Book. During the same decade, the method gained more ground thanks to the academic work of Otto Eckstein, John Krutilla and others. In the mid-1960's, Barbara Castle promoted the analysis as a Minister of Transport in the UK. By 1970, SCBA was already attracting considerable interest which led to the development of more precise cost-benefit rules created by multiple authors. However, in the early 1980's the use of the method was limited, as structural reforms replaced piecemeal interventions. Almost a decade later, SCBA started gaining its popularity back due to the increasing public awareness of environmental issues and the associated demand that such costs should be considered while evaluating policies. Nowadays, SCBA is a method that adapts in different contexts and can be used by various entities such as governmental agencies, courts, progressive interest groups and private corporations [111], [112].

5.1.2 Main Concept & Types of SCBA

To give a more comprehensive definition to the term, Social Cost-Benefit Analysis is a widely applied method of economic assessment which allows the evaluation of the costs and benefits - both direct and indirect - of a certain initiative. The term "initiative" may refer to policies, programs, projects regulations, demonstrations and other governmental interventions. The main characteristic of the method is that it doesn't focus only on the financial but also on the social consequences of the initiative under investigation. The broad purpose of SCBA is to rationalize social decision making by demonstrating the superior efficiency of a particular intervention compared to the alternatives, including the status quo. In this sense, SCBA is undoubtedly a decision-making tool that contributes to a more efficient allocation of society's resources [111], [113].

There are four major types of social cost-benefit analysis. Each of them aims to help governmental decision making in the following way:

- **Ex ante SCBA**

  This is the most typical type of SCBA and it is conducted before the start of the project/policy under consideration. The contribution of ex-ante SCBA to public decision making is direct and very obvious; after its conduction the government is able to access whether or not resources should be allocated to this specific project/policy or to another alternative [111].

- **Ex post SCBA**

  This type of SCBA is conducted at the end of the project/policy under evaluation. By that time all the costs are "sunk", which means that resources have already been utilized for the completion of this project/policy. The contribution of ex-post SCBA is less direct but yet very useful, as it provides valuable information to government managers, politicians and academics not only about the undertaken project but mainly about the worthiness of similar “class” future projects [111].

- **In media res SCBA**

  This type of SCBA is performed during the course of the life of the project/policy under investigation. The contribution of in media res SCBA is double: its conduction determines whether or not to continue a specific project/policy but it also provides information that can be used to predict costs and benefits in future ex-ante analyses [111].

- **Comparative SCBA**

  This type of SCBA compares an ex-ante with an ex-post (or in media res) SCBA of the same project/policy. It is mainly used to unveil to policy makers the efficacy of SCBA as a decision-making and evaluative tool. Unfortunately, there are only a few examples of this comparative type available in the literature [111].

5.1.3 Basic Steps of SCBA

Conducting a detailed social cost-benefit analysis can be complex, confusing and time-consuming. In order to make it more practical and manageable, the whole procedure is broken down into nine basic steps of implementation. More precisely, a SCBA analyst should proceed as follows [111]:

1. Specify the set of alternative projects.

At the beginning the analyst should specify the set of alternative projects that are going to be studied, as SCBA compares the net social benefits of investing resources in one or more potential projects with the net social benefits of a project that would be displaced if the project(s) under evaluation were to proceed. The term “net social benefits” (NSB) refers to the social benefits (B) minus the social costs (C) of the projects taking part in the analysis. The displaced project is often called the *counterfactual* and usually it is the *status quo*, which means there is no change in government policy.

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

At this stage the analyst decides whose benefits and costs should be counted. Depending on the nature of the project and the government’s appraisal, the analyst may be asked to take a provisional, national or even global perspective. However, the issue of standing can prove to be a controversial matter.

3. Identify the impact categories, catalogue them, and select measurement indicators.

At step 3 the analyst has to identify all the physical impact categories of the proposed alternatives (both inputs and outputs), catalogue them as benefits or costs, and specify the measurement indicator of each impact category. The prerequisite so that a physical outcome of the project is regarded as an impact is to establish a cause-and-effect relationship with the entity of people with standing. In some cases, this relationship is easily demonstrated but in some others it may be the result of an extensive review of scientific and social science research. The specification of impact measurement indicators usually happens at the same time as the specification of the impact categories. The analyst chooses the measurement indicators based on the availability of data and their ease of monetization, something that is essential for step 5 of the method.

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

The impacts of almost every project are long-term. At step 4 the analyst has to quantify all these impacts in each time period. The procedure of predicting impacts quantitatively is very important but also very difficult, especially when projects are unique, have long time horizons, or the relationships among their variables are complex.

5. Monetize (attach money values to) all impacts.

At step 5 the analyst monetizes the impacts of the project under evaluation. That means that he/she has to express the value of the above mentioned impacts in terms of dollars or other currency. The value of an output is typically measured by the "willingness-to-pay" of the people with standing. Where markets exist and work well the willingness-to-pay can be estimated from the appropriate market demand curve. However, problems arise where markets do not exist or do not work well; then market prices do not depict the social costs and benefits objectively. Attaching monetary values to such impacts (e.g. the value of a statistical life saved) can be the result of a life's work. To overcome this barrier, most SCBA analysts use "plug in" values found in previous scientific research, whenever possible.

6. Discount benefits and costs to obtain present values.

As already mentioned, almost every project has impacts that arise over the years. To be able to aggregate and compare the total impacts of different projects, regardless of the time-period they occurred, a SCBA analyst has to discount future costs and benefits relative to present costs and benefits in order to obtain their present values. The procedure of discounting is important for SCBA because: Firstly, there is an opportunity cost to the resources used in a project and secondly most people prefer to consume now rather than later.

For a project with a life span of *n* years, the present value of its benefits [*PV(B)*] and costs [*PV(C)*] in year *t* can be estimated with the use of the following formulas:

$$PV(B) = \sum_{t=0}^{n} \frac{B_t}{(1+s)^t}$$

$$PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1+s)^t}$$

, where B_t and C_t are the benefits and costs in year *t*, respectively. The coefficient *s* represents the social discount rate and the expression $1/(1+s)^t$ is known as the discount factor. Discount factors' values always lie between 0 and +1.

7. Compute the net present value of each alternative.

After calculating the present value of the project's benefits and costs, the analyst continues with computing the net present value (*NPV*) of the project, as the result of the difference between the present value of the benefits and the present value of the costs:

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

If the analyst is examining a single alternative project (relative to the status quo), then his recommendation should be to adopt it, if *NPV>0*. A positive *NPV* implies that the present value of benefits exceeds the present value of costs, so the implementation of the specific project would be beneficial for the people with standing. If the analyst is examining more than one alternative to the status quo and all of them are mutually exclusive, then his recommendation should be to adopt the one with the largest *NPV*, assuming that at least one alternative has a positive *NPV*. If none of them has a positive *NPV*, then no project should be undertaken and the status quo should remain intact. It should be clarified that the *NPV* of a project and the present value of the net social benefits (*NSB)* of a project have the same meaning. Thus, the project with the largest *NPV* is also the one with the largest *NSB*.

8. Perform sensitivity analysis.

Before making the final recommendation for a project, a sensitivity analysis should be performed. During this procedure, the analyst changes the values of certain key parameters and recalculates the "altered" *NPVs* of the project under investigation. The conduction of a sensitivity analysis is essential, considering the great uncertainty of SCBA in predicting the project's costs and benefits and in attaching representative money values in each of the impacts. After all, it is important to remember that *NPV*s are estimated values and a sensitivity analysis may reveal that the project with the highest *NPV* is not the best alternative in all circumstances. In theory, every assumption made in a SCBA can be varied. However, in practice, it is more informative if the analyst uses his critical thinking to make the most important assumptions and examines carefully only these scenarios.

9. Make a recommendation.

The final step for the SCBA analyst is to recommend the adoption of the project with the highest *NPV*. At this point it should be noted that the analyst makes recommendations, not decisions. SCBA suggests how resources should be allocated but it is not the basis on which the actual decisions are made. However, due to the fact that it promotes the rational allocation of society's resources, it should be treated as a valuable input to the political decision making process.

5.1.4 Conceptual Foundations of Social Cost Benefit Analysis

In order to determine whether SCBA can be used as a decision rule, as an addition to a study or should be completely avoided, one has to understand the conceptual foundations of the method. As mentioned previously, SCBA is a tool that, in a broader sense, measures the efficiency of alternative projects. This efficiency is best described by the term *Pareto efficiency*, which definition is the following [111]:

"An allocation of goods is Pareto efficient if no alternative allocation can make at least one person better off without making anyone else worse-off" [111].

SCBA, in terms of positive social net benefits, and Pareto efficient policies are related directly to each other because: "*If a policy has positive net social benefits then it is possible to find a set of transfers, or "side payments" that make at least one person better off without making anyone else worse off"* [111].

The connection between SCBA and Pareto efficiency show more clearly by explaining how benefits and costs are measured in this method. The outputs of a proposed policy should be valued based on the **willingness to pay** (WTP) method. The WTP of an individual depicts the payments that he would have to make or to receive (willingness to accept) under the policy, so that he would be indifferent between the status quo and the policy with the payments. On the other hand, the inputs or resources required to implement a policy should be valued based on their **opportunity cost**. The opportunity cost of using an input to implement a policy is its value in its best alternative use. In other words, opportunity cost measures the value of what society must forgo to use the input for the realization of a particular project [111].

As long as analysts value all impacts in terms of willingness to pay and all inputs in terms of opportunity costs, the sign of the net social benefits indicates whether it would be possible to compensate those who bear costs sufficiently so that no one is made worse off and at least one person is better off. Positive net benefits indicate that there is potential for compensation and the project could be Pareto efficient; negative net benefits indicate the opposite [111].

Keeping the above analysis in mind, a SCBA analyst could be appealed to form the following decision rule for SCBA: Adopt only the actual Pareto efficient projects after providing full compensation to all those who bear costs, so that there will be no losers but only winners. However, this is practically impossible to achieve; thus SCBA uses an alternative and more feasible decision rule, which is based on the **Kaldor – Hicks criterion**: "*a policy should be adopted if and only if those who will gain could fully compensate those who will lose and still be better off*". This rule is called the **potential Pareto efficiency rule** or the **net benefits criterion** and according to that, a policy should be adopted when it has positive net social benefits, as only then it is at least possible that losers could be compensated and the policy could be Pareto improving [111].

5.1.5 Valuing of Benefits & Costs

When conducting a SCBA, the analyst's task is to estimate the changes in the net social benefits that occur as a result of implementing a new policy or project. As mentioned earlier, these changes derive from the difference between total consumer benefits and total producer costs and are directly associated with the changes in social surplus.

In microeconomics social surplus is expressed as the sum of consumer surplus, producer surplus, and government surplus. In case no impacts on government are observed, the social surplus can be calculated by the following simplified equation [111]:

$$Social\ Surplus = Consumer\ Surplus + Producer\ Surplus$$

Consumer surplus measures consumers' benefits from their participation in a market. More precisely, it measures the amount that consumers are willing to pay for a desirable good minus the amount they actually pay for it. Consumer surplus and the demand curve of a good are closely related to each other. The demand curve shows the maximum amount that consumers are willing to pay for a given market quantity of the good; thus the price given by the demand curve represents the marginal consumer's willingness to pay. As depicted in figure 28, consumers' total benefits are given by the shaded area OCDE and consumers' total expenditures by the rectangle OBDE. Consumer surplus is the difference between these two, represented by the area BCD which is formed under the demand curve and above the price line, from the origin to the quantity purchased [114], [115].

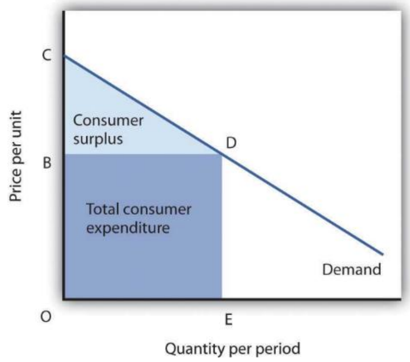

Figure 28: Consumer Surplus [115]

Producer surplus is the "supply" equivalent of consumer surplus and as such, it measures producers' benefits from their participation in a market. More precisely, it measures the amount that producers actually receive from the sale of a good minus the opportunity costs of producing it. Similarly, there is a direct connection between producer surplus and the supply curve of a good. The supply curve shows the minimum amount that producers are willing to accept for a given quantity of a good; thus it represents the willingness to sell (or the cost) of the marginal producer. In figure 29, producers' total revenues are given by the rectangle OBDE and producers' total costs by the area OADE. Producer surplus is again the difference between these two, represented by the area ABD which is formed above the supply curve and below the market price, between the origin and the quantity sold [114], [115].

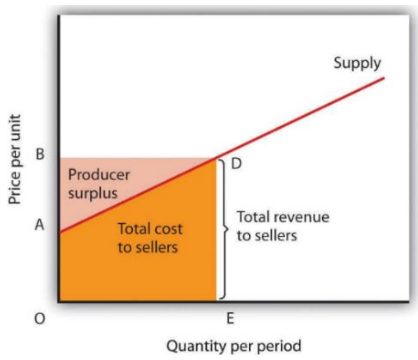

Figure 29: Producer Surplus [115]

In a perfectly competitive market the social surplus is depicted in figure 30, where both a demand and a supply curve are sketched. Consumer surplus is the area BCD, producer surplus is the area ABD and social surplus is the sum of the previous two, area ACD [111]:

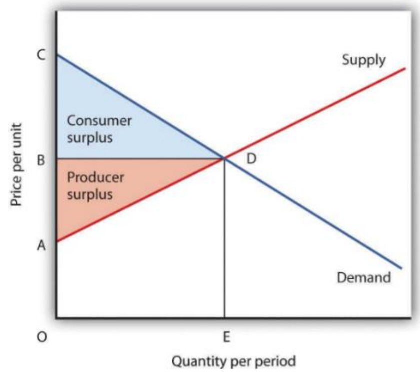

Figure 30: Social Surplus in a competitive market [115]

However, in most cases proposed projects or policies do have influences on governments which should be included in the SCBA. The project's net budget impacts on government constitute the government surplus. The latter is calculated based on inflows such as taxes and outflows such as expenditures. Thus, the social surplus in its complete form is expressed by the following equation [111]:

$$Social\ Surplus = Consumer\ Surplus + Producer\ Surplus + Government\ Surplus$$

The analysis presented so far applies to the valuing of impacts in perfect markets, where the changes in social surplus can be directly estimated based on the existing functional forms of the supply and demand curves in the relevant market, before and after the policy change. However, in practice, these curves are usually unknown and the analyst has to figure out different ways of estimating the costs and benefits. Alternatively, he may conduct experiments, quasi experiments or try to estimate the demand and supply curves himself, based on available information such as elasticity, slope or observations on the prices and quantities of the relevant good [111].

In imperfect markets, where observed prices of certain "goods" (e.g. human life, pollution, recreational areas, etc.) fail to reflect accurately their social value or observed prices do not even exist, it may be inappropriate to use or impossible to estimate the market demand and supply curves directly. Imperfect or distorted markets are commonly encountered and are characterized by some kind of market failure such as monopoly, information asymmetry, externalities, public goods or addictive goods. In such cases, an alternative approach called ***shadow pricing*** is used to measure the costs and benefits. By means of this technique, analysts try to approximate what the market price of the relevant good would be, if it was traded in a market where the demand curve measured marginal social benefits and the supply curve measured marginal social costs. In other words, they attempt to adjust the market price of the relevant good in order to reflect as much as possible its real economic value from society's point of view, eliminating the effects of distortions. As a result, shadow prices of goods can differ significantly from their corresponding market prices. At this point it should be emphasized that most of the times shadow pricing is a difficult task, as the information necessary for its conduction may not be readily available from the observed market data. [111], [116], [117]. The estimation of shadow prices can be performed by two main type of methods that are based on:

- **Revealed preference:** Although a market for the good or service of interest may not exist, its value (shadow price) may be reflected indirectly in the market of a related good. Such methods are: Market Analogy Method, Trade-off Method, Intermediate Good Method, Asset Valuation Method, Hedonic Pricing Method, Travel Cost Method, and Defensive Expenditures Method [111].
- **Stated preference:** Analysts design questionnaires to elicit people's willingness to pay for changes in quantities or qualities of goods. These methods are called *contingent valuation surveys* and some of them are: the open-ended willingness-to-pay method, the closed-ended iterative bidding method, the contingent ranking method, and the dichotomous (binary) choice or referendum method [111].

However, SCBA analysts do not use the above methods very often, as they are time consuming and resource intensive. Instead, they prefer a more direct and less costly approach, in which shadow prices are retrieved from previous studies. These already existing values are called "*plug-ins*" and their use is known as *benefit transfer* or *information transfer*. Some examples of plug-ins typically used in SCBAs are the value of statistical life, the cost of various kinds of injuries, the cost of crime, the value of time, as well as, per-unit values of recreational activities, specific species of flora and fauna, water and air pollution. Ideally, in every particular SCBA plug-in values should be adjusted in order to reflect more accurately the preferences of the population with standing [111].

5.1.6 Limitations of SCBA & Alternative Methods

SCBA may be a very useful tool for comparing the efficiency of alternative projects or policies but it has certain limitations that, under given circumstances, make its use impossible or inappropriate. In such cases, the analyst should be able to realize the insufficiency of SCBA and apply alternative approaches, the most important of which are presented thereafter.

One factor that imposes serious limits to the usage of SCBA is the way of calculating the net benefits of a project itself, as it relies on the quantification and monetization of all of its relevant impacts. Due to certain constraints in time, theory, data or analytical resources, it may be impossible for an analyst to value all these costs and benefits in terms of money. In cases where the above described problem is encountered, one of the following alternatives can be performed instead [111]:

- **Qualitative SCBA:** In conducting this technique, the analysts typically monetize as many of the impacts as possible and then make qualitative estimates of the relative importance of the remaining costs and benefits [111].
- **Cost-Effectiveness Analysis:** This technique is performed when analysts are unable or unwilling to monetize the most important impact of the project under investigation. To overcome this obstacle, they construct a ratio involving the quantitative, but non-monetized, benefit and the total costs. By comparing these ratios of alternative projects they are able to rank them in terms of cost-effectiveness but, unfortunately, not in terms of greater efficiency. CEA is mostly used to assess new policies in the defense and health sectors [111].

Another significant limitation of SCBA is that it focuses on the efficiency of a project or policy. Although efficiency is almost always one very considerable goal in policy assessment, other goals such as equality of opportunity, equality of outcome, expenditure constraints, political feasibility, and national security may be as, or even more, important. In such instances, analysts can better perform one of the following methods [111]:

- **Multigoal Analysis:** The main concept of this technique is that all policy alternatives should be compared in terms of all the relevant goals. During its conduction, three main steps can be distinguished: First, the general goals relevant to the alternative policies under study should be classified into specific impact categories of evaluation. Second, each alternative should be evaluated with respect to each of the impact categories. Third, as no policy alternative is likely to prevail among the others in terms of improvement in all of the goals, a final recommendation should be made based on the analyst’s subjective judgment [111].
- **Distributionally Weighted SCBA:** This technique is appropriate in the special case in which efficiency and equality of outcome are the only relevant goals. According to this method, net benefits are calculated for each of several relevant groups distinguished by income, wealth, or some similar characteristic of relevance to a distributional concern. Then, the net benefits of each group are multiplied by a weighted factor selected by the analyst to reflect some distributional goal and then summed to arrive at a number that can be used to rank alternative policies [111].

5.2 Practical Application of SCBA to Solar PV Projects

5.2.1 Implementation of SCBA in RES

After introducing the main aspects of SCBA, it is time to present how this method can be implemented in renewable energy projects, since the purpose of this thesis is to conduct a SCBA for solar photovoltaics of large scale in Greece. To define the term, SCBA applied to energy is the appraisal of all the costs and all the benefits of an energy project, policy or activity, whether marketed or not, to whomsoever accruing, both present and future, in so far as possible in a common unit of account [112]. Conducting this method in projects or policies of the energy sector can be very helpful, as its results can be used to:

- Assess the economic efficiency of individual renewable energy projects
- Rank, based on their net social benefits, a set of possible projects (e.g. the construction of a PV-plant at different possible locations)
- Compare investments in different forms of renewable energy
- Assess the benefits and costs of possible revisions to already existing energy policies (e.g. setting new targets for the amount of RES consumed and produced in a country)
- Compare alternative policy instruments for achieving a given target (e.g. comparing green certificates with feed-in tariffs) [118].

The performance of SCBA when applied to renewable energy projects follows the same pattern as when applied to any other kind of project. As the analyst has to include all the relevant impacts in order to assess the efficiency of a project, he completes the procedure in two essential parts: the financial and the socio-economic part.

While conducting the financial CBA, the analyst takes into account the impacts that a private investor would use to appraise the profitability of an investment activity from his individual point of view. These costs and benefits are known as internal and in the case of energy projects costs are the investment costs, operation and maintenance costs, fuel costs, taxes, insurance, etc., and benefits are the investor's profits from selling the produced energy [119], [120].

In the socio-economic CBA, the analyst considers the impacts that appraise the project's contribution to the welfare of a region, not as a private investor but from the whole society's point of view. These costs and benefits are called external (or externalities) and they arise when the social or economic activities of one group of persons have an impact on another group and that impact is not fully accounted, or compensated for, by the first group. As we have already mentioned, such externalities are not included in the market price of a good and are difficult to quantify and monetize, due to the lack of adequate data/knowledge and to the lack of an accurate monetary estimation that would reflect their real value to society (shadow pricing and similar methods contain considerable uncertainty). Examples of such impacts are climate change, environmental pollution, damage of human health, security of fuel supply, depletion of resources, employment, etc. [121], [122].

5.2.2 Financial CBA: Costs and Benefits of PV Projects

The current sub-chapter attempts to collect and present the impacts of solar PV projects with respect to the financial part of CBA, necessary for our later calculations. In practice, these impacts are the costs and benefits in which a private investor, who focuses only on income generation, would be interested and are described in more detail below.

5.2.2.1 Costs of Solar Energy

The energy produced by a PV system is determined by the capital cost (CAPEX), the variable costs (OPEX), the level of solar irradiation at the location of installation, the efficiency of the cells and the discount rate at the time of the investment. The most critical of those are the capital cost, the cost of finance and the efficiency. Therefore, to achieve significant reductions in the total costs of a PV system in the future, these particular parameters have to be improved [123].

- **CAPEX COSTS**

The capital cost (CAPEX) of a PV system consists of the **PV module cost** and the **balance of system (BOS) cost**. The PV module cost is the cost of the interconnected array of PV cells forming the module and comprises of raw materials' costs, silicon prices, cell processing/manufacturing and module assembly costs. Its value typically ranges between 1/3 and 1/2 of the total capital cost of the system, depending on the size of the project and the type of the module. However, retrieving accurate data on PV module prices is a difficult task, as they depend on a variety of factors such as the structural cost of the manufacturer, the modules' efficiency and other market features. Figure 31 outlines the trends in PV module prices by technology and origin for the period 2009-2014. As depicted in the graph, the average price of a PV module is approximately 0.7-0.8 €/W. Although the price differences of PV modules between the three major regions of manufacturing are decreasing, the Chinese domestic market still shows the lowest costs, due to its hyper-competitive market and low labour costs. One more observation coming from the graph is that over the years the rate of decline in PV module prices is slowing down. However, with the PV market still growing rapidly, projections of cost reductions can quickly become out of date. Given the current low level of prices, further cost reductions in the prices of PV modules are expected to be more modest in the future. Therefore, the next great challenge for the solar PV industry is to improve even more the competiveness of PV systems, focusing on alternative ways to reduce BOS costs instead of PV module costs [123], [124], [125], [126].

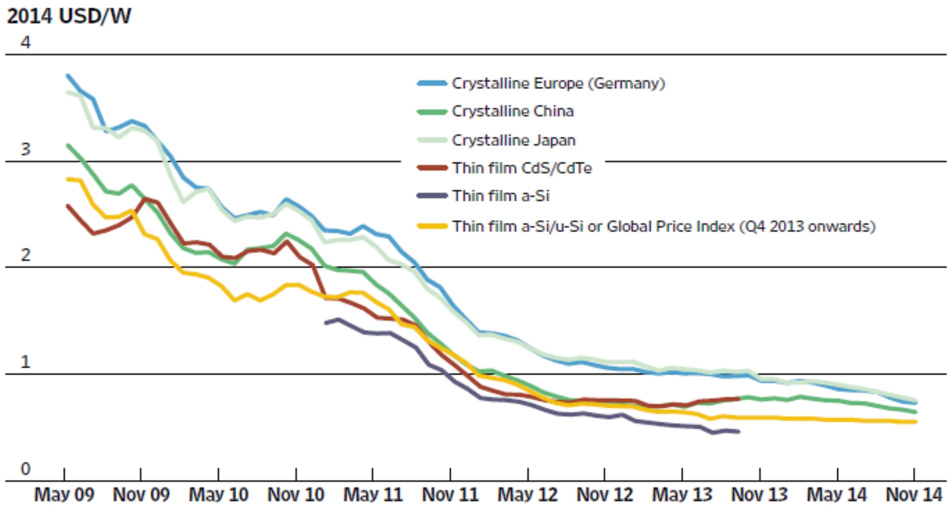

Figure 31: Average monthly solar PV module prices by technology and manufacturing country sold in Europe between 2009-2014 [124].

Regarding the balance of system costs, these consist of:

- The inverter, necessary for the conversion of the PV's output DC current to AC current
- The components needed for mounting and racking the PV system
- The combiner box and other electrical components (e.g. transformers, switchgears)
- The site preparation (e.g. roof preparation for residential systems or site preparation for utility-scale plants), the installation, grid-connection activities and the labour costs
- The Battery storage for off-grid systems, if required, and
- Other "soft" costs such as system design, management, legal, permitting, documentation, project development costs, customer acquisition costs and any upfront financing costs [123].

Many factors can affect the magnitude of BOS costs of a PV system. The most essential is the nature of the installation. As economies of scale and purchasing power play an important role in such investments, large utility-scale systems are usually cheaper than large ground-mounted commercial or residential ones, which are in turn cheaper than small-scale rooftop residential ones. Nevertheless, there are exceptions to the above rule; utility-scale PV plants can have higher BOS costs than expected with the addition of a single or two-axis tracking systems that increase the produced energy, hence enhance their efficiency. Two more factors influencing BOS costs are, undoubtedly, the local market conditions and the regulatory environment present within a country and between countries. The diversity is again more obvious for small-scale residential systems, while for utility-scale projects BOS costs converge quickly, as the market in an individual country grows and project-development experience as well as market scale keep the costs low [124], [125].

As the capital costs of a PV system are very project-specific, estimating an exact price for all types of PV systems would not be representative. However, it is out of the scope of the present thesis to study thoroughly the costs of all types of PV installations; large-scale PV projects are the basic objective. Referring to mature markets on the field of solar energy such as Germany, and based on a typical ground-mounted PV system of 1 MW some general prices can be obtained. In this context, recent data of 2013-2014 illustrate that an indicative capital cost of a PV system varies approximately from 900 to 1500 €/kWp with a more common range of 1000 - 1100 €/kWp. The cost breakdown of such a system can be seen in both figures 32 and 33. More specifically, figures 32 and 33 depict the actual costs of each of the components comprising the total CAPEX costs of the 1 MW PV installation in Germany.

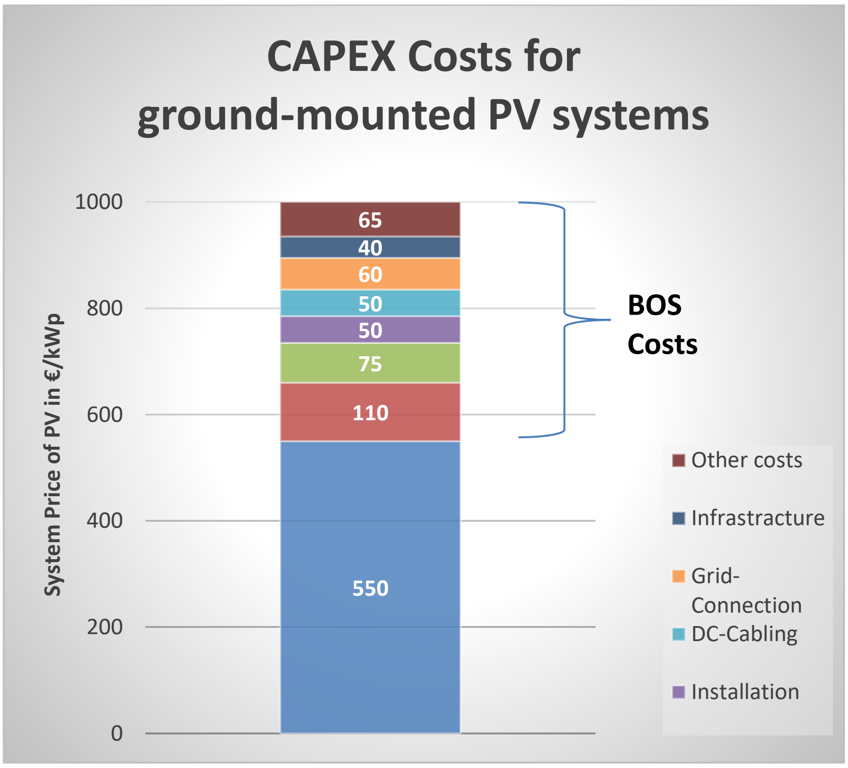

Figure 32: Overview of today 's total CAPEX cost for a ground-mounted PV system of 1 MW in Germany. Created based on data found in [127].

The real prices shown in figure 32 are converted to % percentages and are displayed in figure 33. According to this pie-chart, the component with the highest share of CAPEX costs is the PV module itself with 55% while BOS costs account for the rest 45%. Among the BOS costs, the most cost-intensive component is the inverter with a share of 11% of the total CAPEX costs. Mounting follows with a share of 7.5% and grid connection with approximately 6%. Installation and DC-cabling each account for 5% and infrastructure for about 4%. The remaining BOS cost components, denoted as other costs, are the transformer, switchgear, planning and documentation with a joint share of approximately 6.5% [127].

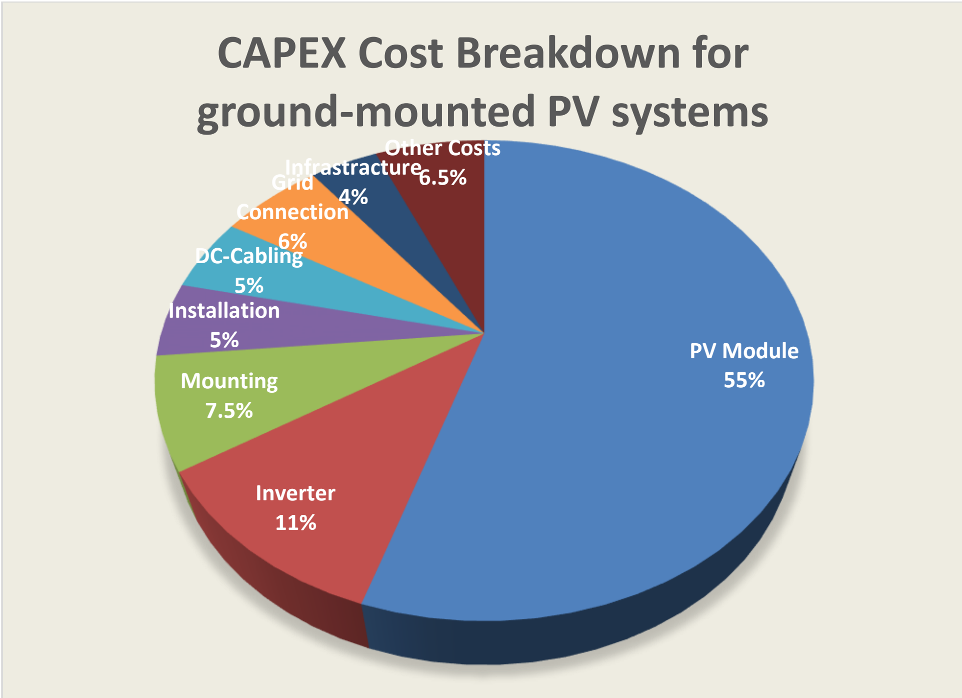

Figure 33: Overview of CAPEX costs breakdown for a ground-mounted PV system in % percentages. Created by data taken from [127].

- **OPEX COSTS**

The variable costs (OPEX) of a PV system are mainly dominated by the annual operations and maintenance (O&M) costs but they also include minor expenses such as unscheduled maintenances, inverter replacements, owner's costs (e.g. rent of land, wages, audits), insurance and property taxes. Although all OPEX expenses should be considered in the financial CBA, O&M costs have the biggest importance, as PV power plants require continual monitoring, periodic inspection, scheduled preventive maintenance and service calls to enhance their long term uptime, performance and economic viability. O&M activities involve scheduled maintenance and cleaning of the panels, both necessary actions to minimize the efficiency losses. For the same reason, system's components must also go through a thorough maintenance checklist regularly such as checking connections of wires, testing voltage and current through wires and modules, inspecting components for moisture, etc. The frequency of O&M activities depends highly on context-specific site features, equipment durability characteristics, system size and performance and site proximity to O&M workforce. However, their execution is recommended once or twice annually. Typically, OPEX costs range from 5 to 25 €/kWp over the lifetime of the PV system, which accounts for 1%-5% of the total costs of the investment [128], [129].

- **LEVELISED COST OF ELECTRICITY**

A usual means of comparison between energy-generating technologies is the Levelised Cost of Electricity (LCOE). By definition, LCOE is the price at which electricity should be produced from a system in order to break even over its lifetime. The LCOE takes into account all the aforementioned investment and operational costs over the system's lifetime, including the fuels consumed and the possible replacement of equipment. It is measured in cost per kilowatt hour (€/kWh) and it is calculated by the following formula [127], [130]:

$$LCOE = \frac{Total\_Lifetime\_Costs}{Total\_Lifetime\_Energy\_Production} \rightarrow LCOE = \frac{CAPEX + NPVofOPEX}{NPVofEP} \rightarrow$$

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{t,el}}{(1+i)^t}}$$

I_0 : Investment expenditures in €

A_t : Annual total costs (O&M, fuel=0 for PV electricity) in € in year t

$M_{t,el}$: Produced quantity of electricity in the respective year in kWh

i : Real discount rate in %

n : Economic operational lifetime in years

t : Year of lifetime (1, 2, …, n)

The magnitude of LCOE may differ significantly between various energy technologies, as it depends greatly on [131]:

- The specific investments for the construction and installation of the power plant
- The local conditions prevailing in the different locations, where the power plant is about to be installed (typical irradiation, wind potential, etc.)

- The full load hours of each energy technology, depending on the type of resource it uses (solar, wind, hydro, etc.) and the type of plant (base, medium or peak load power plant)
- The operating costs during the power plant's lifetime
- The operational lifetime of the power plant and
- The financing conditions of the relevant market or other country-specific parameters.

A relatively low value of LCOE indicates that energy is being produced at a low cost and the returns for the investor are most probably high. Yet, it is more informative to compare LCOE against a benchmark rather than use it as an absolute value. In our case, these benchmarks are the prices in the respective segments of the given solar PV market and they depend on the kind of application. For residential or commercial systems, LCOE should be compared to the residential or commercial electricity retail rates and for large utility-scale solar plants to the power purchase agreements, signed between the seller and the buyer of the produced electricity. In occasions where the LCOE of an energy technology is as low as the respective market prices, it is said that the technology has reached "Grid Parity" [132], [133].

Specifically, for utility-scale PV plants that are the objective of this thesis, latest research showed that at three different European locations (Germany, France & Spain) with energy yield in the range of 1190-1680 kWh/kWp at optimal module orientation, the LCOE fluctuated between 5.4-8.4 ct€/kWh. These values were estimated assuming a real discount rate of 5% that, according to industry experts, describes a reliable and secure long-term financial situation for the investors. On the contrary, in situations characterized by regulatory or political uncertainty, where the real discount rates were higher than 5%, the calculated LCOE range was significantly higher. Figure 34 below illustrates the great dependence of the calculated LCOE on the changes of real discount rates for the particular case of Spain in 2014 [127].

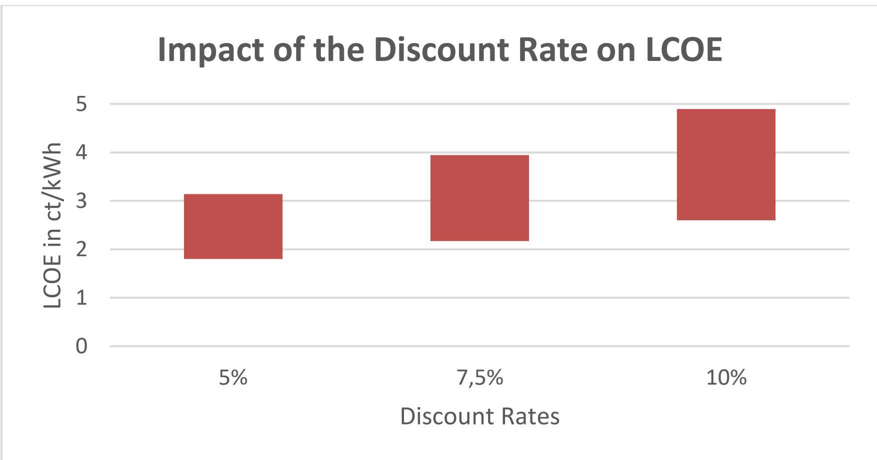

Figure 34: Sensitivity analysis on the discount rate for the case of Spain in 2014. Created by data taken from [127].

To conclude, LCOE is a useful tool that creates a level economic field regardless of how the energy is produced, allowing comparisons among all methods of electricity production. Nevertheless, it is not suitable for determining the financial feasibility of a power plant and the conduction of a more thorough financial analysis, including all revenues and expenditures, is always necessary [127], [134].

5.2.2.2 Benefits of Solar Energy

From the private investor's point of view, the benefits of solar energy are mainly his revenues from selling the produced electricity to the electricity buyers. The price at which this trade takes place is called the price of solar energy and it should be considered in two different ways:

- As the retail price of electricity that is paid by the customers, with pricing depending on the type and volume of their contract and
- As the wholesale price of electricity that is paid by the suppliers to the producers of electricity.

In fact, the retail and the wholesale price of electricity are directly connected to each other; the retail price is the result of summing up the wholesale price paid by the suppliers, the electricity generations costs, the transmission and distribution grid costs and the applicable taxes [135].

The benefits of solar energy to an investor can be enhanced through certain incentives, granted by various authorities such as central governments, regional states, provinces, municipalities and sometimes by utilities themselves. These incentives can either be unique or combined with each other. They are quite frequently subject to policy changes in an attempt to reflect as much as possible the prevailing financial situation by the time of the investment. These incentives - or alternatively support schemes- for RES in general but also for solar PVs in particular have been presented in chapter 3. However, for the sake of completeness a short summary of them follows [136]:

- **DIRECT CAPITAL SUBSIDIES**

As we have already mentioned, solar PV systems are capital intensive investments. In order to promote their implementation, a lot of countries have adopted policies that reduce the high up-front investment costs. These subsidies belong to the government expenditures and are limited by their capacity to free up enough money [136].

- **FEED-IN TARIFFS (FITs)**

Feed-in tariffs guarantee that power plant owners will receive for a certain time-period a fixed payment for the electricity units they produce, independent of the electricity market price. The successful implementation of FIT systems has been observed in countries such as China, Germany, Italy and Japan. What makes the FIT systems attractive is their high effectiveness in combination with their low risk premiums. However, this effectiveness can be significantly decreased, if the prices of tariffs are not reflecting the actual costs of the energy production [136], [137].

- **FEED-IN PREMIUMS**

The feed-in premiums encourage power plant owners to sell the electricity they produce straight to the electricity market by providing them with an additional payment on top of the electricity market price, either as a fixed payment or adapted to changing market prices [137].

- **QUOTA OBLIGATIONS**

Quota obligations are generation-based, quantity-driven incentives. The authorities determine a specific share of electricity that should be produced by RES, which all power plants are obliged to meet. In order to achieve the target, utilities not able to produce renewable energy themselves turn to the purchase of special certificates available on the market. These certificates are usually called "tradable green certificates" (TGCs) or "renewable portfolio standards" (RPS). The trade of the above mentioned certificates provides an additional income for the power plants that produce excess renewable energy, on top of the common market price of the energy they finally sell [136], [137].

- **ELECTRICITY COMPENSATION SCHEMES**

In order to promote RES investments, several countries have already adopted schemes allowing local consumption of electricity, often referred to as self-consumption or net-metering schemes. In general, these schemes allow self-produced electricity to be deducted from the electricity bill of the PV owner, on site or between distant sites, by considering either the real energy flows or the financial flows produced [136].

- **OTHER SUPPORT SCHEMES**

In addition to the aforementioned support schemes, low interest loans and tax exemptions can also be used in order to attract investors in the RES sector [137].

5.2.3 Socio-Economic CBA: Costs and Benefits of PV Projects

This sub-chapter elaborates on the impacts of solar PV projects with respect to the socio-economic part of CBA. These impacts can be either positive or negative and are known as *'external costs'* or *'externalities'*. Energy externalities are defined as the costs or benefits imposed on society and the environment that are not accounted for by the producers and consumers of energy. As a consequence, their value is not reflected in the market price. Most commonly, they are classified into two main categories: environmental externalities such as the costs of damages to the environment and human health, and non-environmental externalities such as the impacts of employment, security of energy supply, etc. [138], [139], [140].

Traditional financial appraisals of energy projects tend to overlook externalities, partly or completely, considering them as of secondary importance compared to conventional costs. However, this reasoning doesn't reflect reality as externalities can affect significantly the total costs and benefits of the energy projects under evaluation. In fact, several international researches reveal that conventional energy sources are characterized by high levels of external costs, while renewables by very low ones. In other words, the evaluation of energy projects taking into account externalities as well shows that renewable technologies are more competitive and cost-efficient compared to conventional ones, even though their initial investment costs may be notably higher [138], [141].

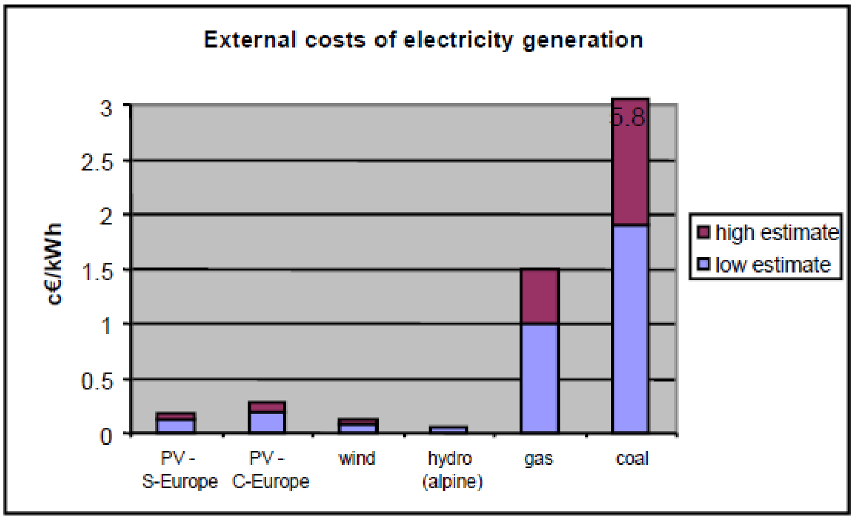

Figure 35: Comparison of external costs between various electricity-generation technologies [142].

It is obvious that due to their high importance, externalities should always take part in decision making. Their ‘internalization’ can be achieved by implementing adequate policy measures such as taxation, adjusted electricity rates, emission trading or otherwise. However, assigning values to externalities is not an easy task as it can be subject to uncertainties, risks and ethical restrictions. Therefore, a series of valuation studies conducted by governmental authorities, such as the European Commission, the US Department of Energy and the UK Department of Trade and Industry, have tried to estimate the external costs of various energy-generating technologies. These studies are available in the literature and provide reference values to be used in similar contexts. Although this field has already been enriched with several empirical and theoretical developments, a lot of work still needs to be done in order to improve the current knowledge and extend the range of externalities considered [143], [144], [145].

In the next sections of this sub-chapter the externalities of solar PV projects will be presented and quantified, with particular reference to the case of Greece. These monetized plug-in values will then be used in the analytical calculations of the next chapter.

5.2.3.1 Environmental Externalities

By definition, the term ‘environmental externalities’ refers to all burdens imposed by an activity on the environment that affect our welfare. Hence it includes impacts of pollution on human health, agriculture, materials, and ecosystems and how the resultant changes in ecosystems affect our actual, potential or future possibilities to use it (recreation, transportation) or the importance we may attach to conserving it (biodiversity) [140].

The conduction of a SCBA for the evaluation of energy projects requires all environmental externalities to be included in the decision process. In order to do so, marginal external costs, which are the additional external costs arising when alternative projects are implemented, need to be calculated and compared. In other words, not only external costs occurring during operation but also the ones occurring during construction, provision of energy carriers and materials, waste disposal, dismantling, etc. (namely all external costs that appear during the full life cycle of each alternative) should be taken into account. Keeping in mind that externalities can have both negative and positive effects on the environment and health, in the case of large-scale solar PV projects, the external costs of conventional electricity production that are avoided because of the use of solar energy instead are considered as positive externalities, while the external costs occurring throughout the full life cycle of solar energy, from the manufacturing of simple solar cells to the final energy production of a PV power plant, are considered as negative [122].

The first attempts to quantify the environmental externalities of energy were made in the late 1980's - early 1990's with the innovative work of the researchers Hohmeyer (1988), Ottinger et al (1990), Bernow et al (1990) and Pearce et al (1992). Since then, many studies have been conducted on the field, with **ExternE** (External Costs of Energy) being one of the most comprehensive. Launched in 1991 by the European Commission, initially as a collaboration with the US Department of Energy and later individually, the ExternE series of projects developed and demonstrated a unified methodology for quantifying the environmental impacts connected with the production and consumption of energy. Starting from early 90's till 2005, the project evaluated the external costs of different fuel cycles in various locations in Europe. ExternE is considered as one of the most advanced projects of its kind with a worldwide reputation and it has already been applied to a large number of national studies to help in the decision making of environmental, energy and transport policies [140], [146].

The ExternE series of projects started with studying and identifying the environmental externalities of various energy-generating technologies. In order achieve this, the impact pathway approach was developed and applied. The latter term refers to a bottom-up-approach in which environmental benefits and costs are estimated by following the pathway from source emissions (via quality changes of air, soil and water) to physical impacts before being expressed in monetary benefits and costs. The use of such a detailed methodology is essential, as external costs are highly site-dependent and as, for the estimation of externalities, marginal costs are of greater interest compared to average costs. All the calculations necessary for the project were performed with the help of a software package named EcoSense. EcoSense provides harmonized air quality and impact assessment models together with a database containing the relevant input data for the whole region of Europe [146].

In terms of environmental externalities, the specific technologies studied by the project were the following [146]:

- **Fossil fuels**: coal and oil technologies with varying degrees of flue gas cleaning, natural gas, centralized systems and CHP, Orimulsion
- **Nuclear**: PWR, open and closed systems for fuel provision
- **Renewable**: onshore and offshore wind, hydro, a wide range of biomass fuels (waste wood, crops) and PV technologies.

Although several environmental impacts could be detected for each of the above mentioned fuel cycles, the ExternE project focused on those that, according to present knowledge, result in the greatest externalities. The specific priority impact categories considered by ExternE for the fossil, the nuclear and the renewable fuel cycle are presented in tables 9, 10 and 11 respectively [140]:

Table 9: Priority Impacts for Fossil Fuel Technologies identified by the ExternE project.

Created based on data found in [140].

PRIORITY IMPACTS FOR FOSSIL FUEL TECHNOLOGIES	
FUEL CYCLE DEPENDENT	**FUEL CYCLE INDEPENDENT**
Effects of atmospheric pollution on human health	Impacts of coal and lignite mining on ground and surface waters
Accidents affecting workers and/or the public	Impacts of coal mining on building and construction
Impacts of noise	Resettlement necessary through lignite extraction
Impacts of global warming	Effects of accidental oil spills on marine life
Effects of atmospheric pollution on: materials, crops, forests, freshwater fisheries and unmanaged ecosystems	Effects of routine emissions from exploration, development and extraction from oil and gas wells
	Effects of routine emissions from exploration, development and extraction from oil and gas wells

Table 10: Priority Impacts for Nuclear Technologies identified by the ExternE project.

Created based on data found in [140].

PRIORITY IMPACTS FOR NUCLEAR TECHNOLOGIES
Radiological and non-radiological health impacts due to routine and accidental releases to the environment
Occupational health impacts from both radiological and non-radiological exposures, due to work accidents and radiation exposure
Impacts on the environment of increased levels of natural background radiation, as a result of major accident releases

Table 11: Priority Impacts for RES Technologies identified by the ExternE project. Created based on data found in [137].

<table>
<tr><th colspan="2">PRIORITY IMPACTS FOR RENEWABLE ENERGY TECHNOLOGIES</th></tr>
<tr><th>HYDRO FUEL CYCLE</th><th>WIND FUEL CYCLE</th></tr>
<tr><td>Occupational health effects</td><td>Accidents affecting workers and/or the public</td></tr>
<tr><td>Employment benefits and local economic effects</td><td>Effects on visual amenity</td></tr>
<tr><td>Impacts of transmission lines on bird populations</td><td>Effects of noise emissions on amenity</td></tr>
<tr><td>Damage to private goods (forestry, agriculture, water supply, ferry traffic)</td><td rowspan="2">Effects of atmospheric emissions (turbines' manufacturing, on site construction and servicing)</td></tr>
<tr><td>Damages to environmental goods and cultural objects</td></tr>
</table>

After the implementation of the ExternE methodology to all evaluated technologies, the following results were obtained [146]:

- Coal technologies can be characterized as the worst energy-generating technologies available, due to their very high CO_2, primary-secondary aerosols and "classical" pollutant emissions (SO_2, NO_x and dust particles).
- Natural gas technologies are slightly better, as they show low levels of classical pollutant emissions. However, the levels of their greenhouse gas emissions can vary significantly, depending strongly on the efficiency of the technology considered.
- Biomass technologies have very low levels of greenhouse gas emissions but the levels of classical air pollutants and other assessed impacts can range from lower to higher external costs, depending on the biomass technologies and the different gas cleaning techniques used.
- For nuclear technology both greenhouse gas and classical pollutant emissions seem to be low, although the low probability of accidents with high environmental consequences as well as the impacts of the nuclear energy fuel cycle were included in the study.
- Concerning RES technologies, wind power exhibits low levels of both classical pollutants and greenhouse gas emissions while photovoltaics are a very clean technology at the use stage, but have considerable life cycle impacts.

In 1998 the ExternE team focused on the evaluation of the external costs of different energy-producing fuel cycles but in different countries of the European Union. This new phase of the project, called the *National Implementation* phase of ExternE, was very important as it took into account site-specific conditions, technologies, preferences, problems and policy issues of each country. Consequently, representative technologies have been studied for each of the participant countries, based on the existing power systems or on the expected development of these systems. The overall results of this phase of the project are gathered in table 12. Due to the fact that only the typical technologies of each European country were considered, several cells of the table are intentionally left blank [146].

Table 12: Results of the implementation and update of the ExternE Accounting Framework in Europe [146].

EXTERNAL COSTS FOR ELECTRICITY PRODUCTION IN THE EU BY TECHNOLOGY (€cent/ kWh *)									
COUNTRY	**COAL & LIGNITE**	**PEAT**	**OIL**	**GAS**	**NUCLEAR**	**BIOMASS**	**HYDRO**	**PV**	**WIND**
AT				1-3		2-3	0.1		
BE	4-15			1-2	0.5				
DE	3-6		5-8	1-2	0.2	3		0.6	0.05
DK	4-7			2-3		1			0.1
ES	5-8			1-2		3-5 **			0.2
FI	2-4	2-5				1			
FR	7-10		8-11	2-4	0.3	1	1		
GR	5-8		3-5	1		0-0.8	1		0.25
IE	6-8	3-4							
IT			3-6	2-3			0.3		
NL	3-4			1-2	0.7	0.5			
NO				1-2		0.2	0.2		0-0.25
PT	4-7			1-2		1-2	0.03		
SE	2-4					0.3	0-0.7		
UK	4-7		3-5	1-2	0.25	1			0.15

* *Sub-total of quantifiable externalities (such as global warming, public health, occupational health, material damage)*
** *Biomass co-fired with lignite*

The ExternE series of projects completed the estimation of external costs of energy at 2005. After this year, several attempts were made in order to continue and extend this valuable work. Many projects such as the ExternE-Pol, DIEM, ECOSIT, INDES, NEEDS, etc. used the ExternE methodology and tools not only to perform their own studies on externalities but also to further develop them towards a more integrated assessment. One remarkable effort towards this direction was the project "New Elements for the Assessment of External Costs from Energy Technologies" (NewExt), which created the base for the project "Cost Assessment for Sustainable

Energy Systems” (CASES) that followed. The latter is a coordination action funded by the European Commission and its main target is to create a consistent and comprehensive picture of the full costs of energy, taking into account not only the external but also the private costs of energy generating technologies. More precisely, the key objectives of the CASES project are [147]:

- To create detailed and reliable estimates of both external and internal costs of energy production for different energy sources on national level for the EU countries and for some non-EU countries, under energy scenarios up to 2030.
- To evaluate policy options for improving the efficiency of energy use, taking into account the full cost data.
- To disseminate research findings to energy sector producer and users as well as to the policy making community.

Following the above short presentation of the ExternE and CASES projects, the results of their implementation for the case of Greece is discussed next. As the thesis examines the transition of PV power plants in Greece within the framework of European Union’s directives, the external costs calculated by all projects are reliable inputs to our calculations. However, due to the fact that the CASES project is the most recent one and includes the externalities of solar fuel cycle in Greece as well, all relevant values necessary for the next chapter will be taken from the CASES database.

THE CASE OF GREECE

The environmental benefits of photovoltaics consist of the costs avoided when energy is generated by PV instead of conventional power plants. As mentioned earlier, the estimation of such externalities for many European countries was achieved through the national phases of the ExternE and CASES projects. For the case of Greece, the ExternE methodology was applied by the National Technical University of Athens to the six most important fuel cycles taking part in the Greek energy-generation landscape: lignite, oil, natural gas, hydro-power, wind energy and biomass. The obtained damage costs were then aggregated for the country’s whole electricity system, while the usefulness of externalities assessment was illustrated by a policy case study. After the completion of ExternE, the CASES project, following a similar methodology, updated and extended the existing information on external costs of energy [148].

In order to evaluate the Greek case, our interest should focus on the environmental costs caused by fossil fuel power stations burning lignite, oil and natural gas, as these are the most harmful and, unfortunately, the most widespread energy-generating technologies in the country that could be replaced by PV power plants of large scale. The following section begins with a brief description of each of these three main fuel cycles and continues with the estimation of their major externalities for the case of Greece. The section concludes with the presentation of the negative externalities of solar PV energy as well.

Lignite Fuel Cycle

Greece's energy sector is characterized by the presence of limited domestic resources. Electrical power is mainly produced from solid fuels, with lignite being the cheapest thus the most significant one, accounting for 46% of primary energy production in 2013 [149]. Greece is the second largest lignite producer in the European Union, and the sixth largest worldwide. The country has its most important deposits in the north, at Ptolemais-Amynteon and Florina (West Macedonia), at Drama (East Macedonia and Thrace) and at Elassona (Thessaly), as well as in the south at Megalopolis (Peloponnese) [29], [148], [150]. Figure 36 shows the distinct process steps in the typical Greek lignite fuel cycle:

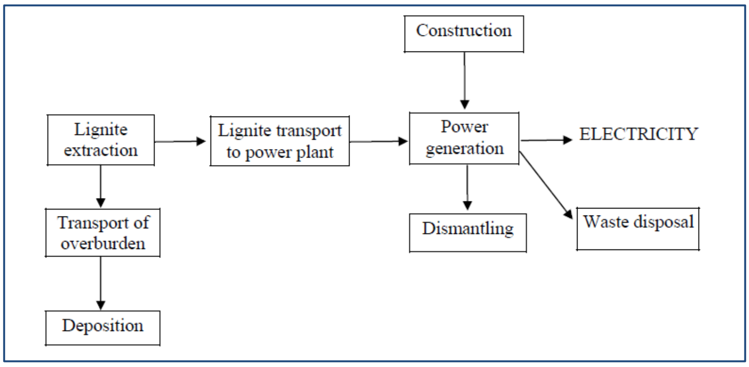

Figure 36: Process steps in the Greek lignite fuel cycle [148].

Oil Fuel Cycle

Greece has some small reserves of crude oil, but its indigenous oil production remains very low. In practice, the country imports all of the necessary oil from other countries, with Russia being the largest supplier followed by Libya, Iran, Saudi Arabia, Kazakhstan and Iraq. In the electricity generation mix, oil accounts for approximately 9.5% of the total electricity production, as reported for 2013 [149]. This share is attributed mainly to power plants located in autonomous systems such as islands which are not interconnected with the mainland grid. Otherwise, oil fired power plants are typically operating only in peak load mode for some hundred hours per year [29], [148], [150]. The typical stages of the technology are displayed in figure 37 below:

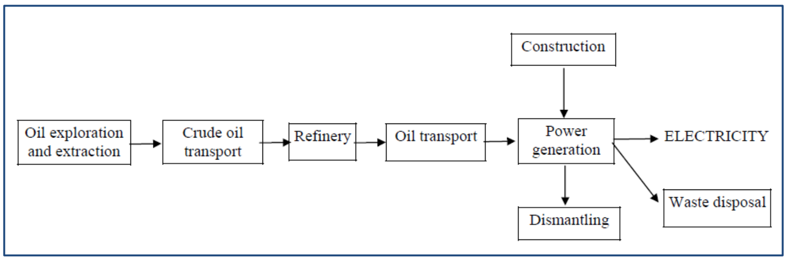

Figure 37: Stages of the oil fuel cycle [148].

Natural Gas Fuel Cycle

Natural gas has only been available in Greece since 1997 and nowadays all necessary quantities are practically imported, as the country's domestic production is negligible. Russia is once again the largest supplier, followed by Algeria and Turkey. The share of natural gas in the Greek electricity system has been increasing, reaching the level of 19% in 2013 [29], [148], [149], [150]. The typical natural gas fuel cycle stages can be seen in figure 38 that follows:

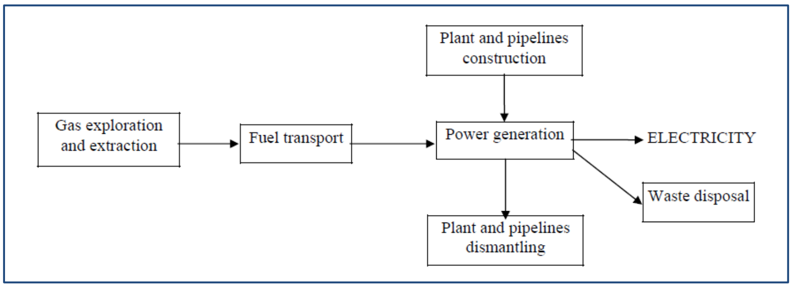

Figure 38: Stages of the natural gas fuel cycle [148].

Regarding the aforementioned fuel cycles, the priority impacts assessed by ExternE were effects on occupational health, effects of air pollutants on public health, agriculture, materials and natural ecosystems and effects of climate change due to the greenhouse gases releases. However, being characterized by major uncertainties, the following areas needed to be further researched and improved [148], [151]:

- Monetary valuation of mortality effects
- Valuation of severe accidents, as the current framework was focusing more on accidents in the nuclear fuel cycle than in other energy sources
- Effects due to global warming, acidification and eutrophication of ecosystems
- Effects due to contamination of water and soil
- Long-term effects due to accumulation processes of persistent substances.

Therefore, the NewExt project concentrated on the improvement of the existing ExternE methodology in these areas, which were the most important for the assessment of external costs, and were expected to be primarily affected by any new scientific developments. NewExt was succeeded by the CASES project, which, among others, applied the "improved" NewExt-methodology on a national level for the countries of the European Union. With the use of the EcoSense 4.0 model, CASES project calculated the external costs for Greece in the framework of a research funded by PPC, in an effort to update the available external cost estimates of the Greek energy sector. The results are shown in table 13 [151], [152]:

Table 13: External Cost Estimates for Greece in €/MWh, as calculated by the CASES project. Created based on data found in [152].

EXTERNAL COST ESTIMATES FOR GREECE (€/MWh)			
	LIGNITE	**OIL (steam turbine)**	**NATURAL GAS (combined cycle)**
	ELECTRICITY PRODUCTION		
Mortality	2.91	2.94	0.28
Morbidity	1.48	1.53	0.16
Accidents	Ng	Ng	Ng
Occupational health	0.07	0.08	0.08
Major accidents (nuclear)	-	-	-
Crops	0.01	0.07	0.01
Ecosystems	Iq	Iq	Iq
Fauna & Flora	-	-	-
Forests	-	-	-
Materials	0.20	0.21	0.01
Monuments	0.02	0.03	0.00
Noise	Ng	ng	0.45
Visual impacts	Ng	ng	ng
Land use	-	-	-
Global warming	23.39	15.51	7.20
Sub-total (1)	**28.09**	**20.36**	**8.18**
	OTHERS STAGES		
Public health	3.69	1.11	ng
Occupational health	0.14	0.04	0.02
Ecological effects	Ng	nq	ng
Road damages	Ng	nq	ng
Water resources	0.01	-	-
Marine environment	-	0.36	-
Materials	-	ng	-
Crops	-	ng	-
Global warming	0.99	0.74	0.02
Sub-total (2)	4.83	2.25	0.05
Sub-total (1) + (2)	**32.92**	**22.61**	**8.23**

ng: negligible, nq: not quantified, iq: only impact quantified, -: not relevant

Comparing the values of table 13, lignite shows the highest total external costs and thus it is the most harmful fuel used in the Greek electricity generation mix. This is mainly a result of its inferior quality, as the Greek lignite deposits contain considerable amounts of Sulphur and are characterized by low heating values. Almost 80% of the quantified externalities occur at production stage and are associated with mortality impacts and with the global warming effect. According to the researchers of ExternE and CASES, the quantifiable damage costs of the lignite fuel cycle are comparable to the actual private cost of lignite electricity, creating a serious distortion of the present market prices which prevents other cleaner fuels from being widely adopted in the electricity generation sector. Electricity generation from oil comes second after lignite, showing less but still significant externalities. In this case as well, almost 82% of the externalities related to mortality effects and the effect of global warming occur at operation stage. Last but not least, electricity generation from natural gas shows the lowest external costs among all compared conventional technologies. Once again, the biggest share of externalities connected to mortality impacts and the global warming effect occur at production stage and, if added, represent approximately 90% of the total external costs of the fuel cycle [148].

Solar PV Life Cycle

Photovoltaics are a power-generating technology characterized by minor negative environmental impacts compared to conventional ones. These effects are in principal site specific, depending on the nature and size of the project, and they can be lessened by applying a series of mitigation measures such as [153]:

- Proper siting of the PV plants, taking into account all alternative locations and expected impacts;
- Good operational practices of the PV plant (e.g. rational use of water, proper waste disposal practices, use of biodegradable chemicals, etc.);
- Appropriate training of workers, in order to familiarize them with the PV system and ensure their safety;
- Sensible assessment of all pre-development constraints (e.g. on water use, on expected CO_2 savings, etc.);
- Adequate informing of the public by the relevant organizations, in order to affirm public acceptance of the PV technology;
- Re-establishment of the local flora and fauna, giving the environment the time to revert to its initial state.

The majority of scientific research conducted on the environmental impacts of solar power so far is based on the life cycle assessment (LCA) framework. The stages of the solar PV life cycle consist of the production of raw materials, their processing and purification, the manufacture of modules and balance of system (BOS) components, the installation and use of the systems for electricity production, and their decommissioning and disposal or recycling. Figure 39 below presents the aforementioned distinct stages [154]:

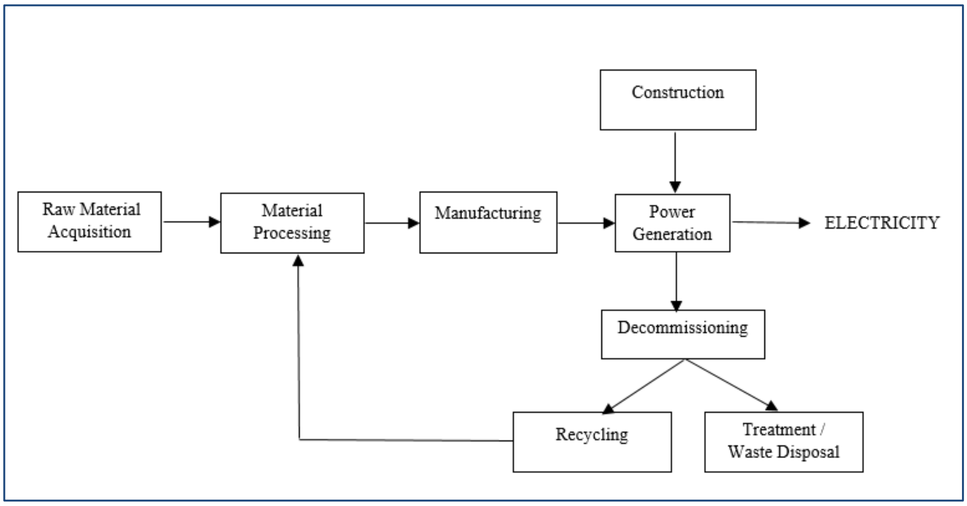

Figure 39: Stages of the solar life cycle. Created based on data found in [154].

Most of the studies examining the environmental impacts of solar PV technology are confined to the evaluation of the greenhouse gas emissions and the energy payback time, while only a few consider more complicated effects such as hazardous materials emissions, land use intensity, water usage and biodiversity. This limitation in resources makes the obtaining of quantitative information on such impacts very difficult. Due to this restriction, in the following paragraphs we analyze qualitatively each of the environmental impacts of the PV life cycle but we present their quantitative values as a total in the conclusion, based on the results obtained from the CASES project [155].

- **<u>Land use & landscape</u>**

The impact of land use on natural ecosystems depends on numerous parameters such as the topography of the landscape, the area covered by the PV system, the type of the land, the distance from areas of natural beauty or sensitive ecosystems, and the biodiversity. The changes on the landscape mostly occur during the construction stage of the PV power plant, as a result of construction and transport activities. Due to those factors, the implementation of a large-scale PV power plant can have negative as well as positive effects on the landscape: on the one hand it can compromise the soil productive areas of a cultivable land and thus create several social disagreements and displeasure to the citizens; on the other hand it can upgrade areas such as brownfields, landfills, mine sites, and other types of contaminated regions, by utilizing them, especially when the reclamation of these lands is prioritized. As about the land use, this is in principal less dangerous during the life cycle of solar power compared to conventional fuels, as it is characterized by less transportation activities, decreased cooling water intake, and lower global warming emissions [153], [156].

- **Biodiversity**

Due to the novelty of the technology, the impacts of large-scale PV power plants on biodiversity are not clearly estimated. Based on the available literature, most of the impacts to wildlife and habitat are caused by the land occupation of the power plant itself. A typical PV installation is surrounded by fences that limit the movement of animals, affecting directly the habitat of the land. Except for animals, vegetation also suffers from significant alterations. During the construction of the plant, the soil is sometimes scraped to bare ground and kept free of vegetation with herbicide, while in other cases vegetation is allowed to grow up to a certain height, so as not to interfere with the efficiency of the panels. Moreover, the PV panels themselves create shadows that change the microclimate and cause an unstudied effect on vegetation [156].

However, it should be pointed out that PV power plants can also have positive effects on the wildlife and habitat of a region. In many cases, the profits of such projects can be used as a funding for mitigation actions, which is in fact very beneficial for the local fauna and flora. A few examples of such actions are: the elimination of invasive or overpopulating species, the construction of suitable habitat for endemic species or the increased monitoring of the ecosystem's state [156].

- **Depletion of natural resources**

One more negative environmental externality of the solar PV life cycle is the great amount of resources necessary for the manufacturing of the PV cells. Unfortunately, the production of current generation's PVs (especially mono and poly c-Si cells), is rather energy intensive and large quantities of bulk materials are required, thus contributing to the exhaustion of natural resources. In order to minimize the environmental impacts relevant to the production of PV cells, several aspects of the present manufacturing procedure should be improved, such as the use of more efficient and safer materials as well as the further development of modules' recycling technology [153].

- **Human health**

The production of PV systems can pose a potential threat to human health and well-being, as it involves the use of toxic and explosive gases, corrosive liquids, and suspected carcinogenic compounds. The magnitude of the implications depends on the materials' toxicological properties, and the intensity, frequency, and duration of human exposure. A possible release of hazardous pollutants can occur mainly during the manufacturing of the PV modules. Additionally, it can be caused by leaching of cracked or broken modules, by irregular plant operations, or by combustion of the modules in the event of fire or excessive heat exposure [153], [157].

Although the amount of toxics used by the PV industry is small, a long-term exposure to them bares health risks to both workers of the production sites and the general public. Workers may be directly affected by the hazardous compounds through the air, ingestion by hand-to-mouth contact, or skin absorption. The general public may be affected through indirect manners, such as through contamination of the drinking water caused by improper disposal or treatment of the plant effluent. In order to protect the working personnel, governments have set tight standards for the chemical concentrations of hazardous emissions exposure of workers during an 8-hour working shift, in addition to the maximum concentrations allowable without the use of protective equipment. Moreover, in order to protect both workers and the public, special control equipment and procedures are implemented in production sites and PV power plants to prevent or minimize unlucky events. The existence of such prevention and safety systems along with the fact that dangerous emissions mostly occur in open space, minimize the human health risks imposed by the use of toxic materials. As a result, the potential harm of human health and well-being by the use of photovoltaic technology is extremely remote [153], [157].

- **Climate change (GHG emissions) & air pollution**

Fossil-fuels in energy generation release high amounts of greenhouse gases (GHG) and other harmful air pollutants (e.g. NO_x, SO_x, etc.) during operation, intensifying the phenomenon of global warming and posing threat to the environment and human health. Although PV technologies do not emit any pollutants during operation, they do produce emissions at the other stages of their life cycle. Those emissions should be taken into account in our analysis as they are part of the negative environmental externalities of solar energy.

As far as climate change is concerned, solar energy technologies help in the mitigation of the phenomenon, as they produce significantly lower amounts of greenhouse gases compared to conventional ones. This is clearly reflected in their low *carbon footprint*, which is a common indicator for assessing the impact of power producing technologies on the environment. In the case of PVs, the term refers to the amount of carbon dioxide (CO_2) and its equivalent of other

GHGs emitted during the PV system's lifetime per kilowatt-hour (kWh). The carbon footprint of PV energy, as calculated for systems located in Southern Europe, ranges between 16-32 g CO_2 eq./kWh, while fossil fuels show much higher carbon footprints in the ranges of 300-1000 g CO_2 eq./kWh. As PV technologies produce practically zero direct CO_2 emissions during operation, their carbon footprints represent all the small, indirect emissions occurring primarily during the manufacturing of the PV systems and secondarily during their transport. The quantities of these emissions depend on the energy mix used and the amount of energy consumed during the process of manufacturing at the production sites. It is worth mentioning that the carbon footprint of PV energy has decreased throughout the last 10 years by approximately 50% and is expected to decrease even more thanks to the several improvements achieved in performance and manufacturing of PV systems as well as in raw-material savings [153], [158].

Regarding the rest of the air pollutants emitted during energy production, NO_x and SO_x are of greatest importance for electricity generation. For technologies such as PV, characterized by no emissions during operation, NO_x and SO_x are released mainly at manufacturing stage and depend on the specific power sources used to manufacture the PV equipment. Generally, life-cycle NO_x and SO_x emissions of solar PV energy are insignificant compared to emissions from conventional power plants [159].

- **Water use and consumption**

Energy and water are interdependent. In general, solar energy technologies show big variation in their water withdrawal (total volume removed from a water source) and consumption (volume of withdrawn water not returned to the source) rates. Especially PV energy systems are represented by low rates of water consumption (0.02 m^3/MWh), using water only for panel washing and dust suppression in places where dust deposition is problematic [156].

- **Geo-hydrological resources**

The negative impacts of PV energy to geo-hydrological resources consist of the erosion of topsoil, the increase of sediment load or turbidity in local streams, the reduction in the filtration of pollutants from air and rainwater, the reduction of groundwater recharge and the increased possibility of flooding. Recent scientific research indicates that the aforementioned effects can be minimized successfully. However, as the research is still at an early stage, continuous studying and monitoring are recommended for the conservation of the local hydrological and soil resources [155].

- **Waste management**

In the case of stand-alone PV systems, the negative impacts of the chemicals included in the batteries of the energy storage should also be taken into consideration. A life cycle analysis of batteries for stand-alone PV systems indicates that the batteries are pose a significant threat to the environment, due to their relatively short life span and their heavy metal content. In addition, a large amount of energy and raw materials are required for their production. In order to improve this situation, a module-recycling scheme should be implemented [153].

- **Visual & Noise intrusion**

Visual intrusion depends highly on the surroundings of the location where the PV power plant is going to be installed. In other words, the higher the value of the installation site (e.g. area of natural beauty etc.) the more significant the visual impact will be. In order to minimize these negative effects, the design and the installation sites of such large-scale PV power plants should be chosen properly [153].

Regarding noise intrusion of large-scale PV power plants, some noise is expected during the construction phase of the plant. However, in general such power plants produce much lower noise levels compared to conventional ones, due to the complete absence of mining and the less transport activities [155].

After theoretically identifying the environmental externalities of solar PV power, the thesis continues with quantifying them in monetary terms for the case of large-scale PV power plants in Greece. As the monetization of such impacts is difficult, the necessary information is retrieved from the already existing literature and more specifically from the CASES project. As already mentioned, the CASES project was conducted in order to assess the full costs of the major energy generating technologies in different countries over the course of 25 years. Although a lot of research has been done in this field, the current study is based on the findings of CASES, as this project is not only a reliable source but also the most recent one on an international level.

In terms of external costs, CASES researchers calculated the impacts of solar PV power, classifying them in four distinguished categories: human health, environment (loss of biodiversity, crops, and material), radio nuclides, and damages of greenhouse gases. They focused on classical pollutants, using country specific data with the help of external partners who assessed their reliability of the dataset and identified the most critical parameters influencing the total cost estimates. Other pollutants were considered as well, using generic data applicable to all countries for the period 2005-2030 with the help of EcoSense software. In order to provide a safe prediction of the expected external costs by years 2020 and 2030, all values were multiplied by the growth rate to homogenize external with private costs [160].

Table 14 below presents the environmental externalities of solar PV energy, as calculated by the CASES project and for the specific case of Greece:

Table 14: Total environmental external costs of solar PV in open space, as calculated by the CASES project for the case of Greece. Created based on data found in [160].

ENVIRONMENTAL EXTERNALITIES	2005-2010 (€/MWh)	2020 (€/MWh)	2030 (€/MWh)
Human Health	4.416	4.194	4.587
Environment	0.145	0.119	0.118
Radio Nuclides	0.003	0.003	0.003
GHG Damages	1.805	1.376	1.816
TOTAL	**6.369**	**5.692**	**6.524**

Environmental externalities are a significant proportion of the total costs of all power-generating technologies. Comparing the values of tables 13 and 14 for conventional and solar PV power generation in Greece respectively, it is clearly depicted that the external costs of photovoltaics are much less compared to traditional Greek lignite, oil and natural gas technologies. In fact, if the external costs of fossil fuels were taken into account, the market price of the corresponding generated electricity would be much higher. On the contrary, solar PV energy in Greece is characterized by a small share of environmental externalities, where the most important parameters are impacts on human health and climate change. It is also worth mentioning that the majority of these externalities arise during the non-operational stages of the technology and mainly during the manufacturing of the PV modules [161].

Regarding the trends of environmental externalities of solar energy in Greece, it can be seen that the most important impacts - human health and climate change - are expected to decrease by 2020 but then increase by 2030. The initial reduction of the emissions per kWh is foreseen thanks to the technological improvements of the PV systems. The following increase can be attributed to the increasing of the willingness to pay from 2020 to 2030, which will result in an increase of the damage costs of these parameters. However, the general levels of environmental externalities reported for solar PV technology in Greece are expected to remain low, showing only small fluctuations in the future [161].

5.2.3.2 Non-Environmental Externalities

As already stated earlier, the external costs of solar energy can also be non-environmental. These externalities refer to various impacts that influence society's welfare which are not taken into consideration by private investors of PV installations. The identification and monetization of non-environmental externalities is even more difficult than the environmental ones, due to the limited sources and publications available on this field. As a consequence, the following section will present descriptions and, wherever available, monetary values of the non-environmental externalities related to the case of Greece that could be found and are relevant to the main objective of the thesis.

- **Job creation**

At times of unemployment, such as in the case of Greece during crisis, the difference between the price and the social cost of labour indicates a potential net economic gain. Consequently, any activity employing additional work force may improve the overall efficiency of an economy. This means that job creation contributes significantly to economic growth, directly affecting the social welfare of all citizens [162], [163].

The potential jobs offered by the PV industry can be divided into the following two categories:

- Direct jobs, provided by companies or individuals directly associated with the whole PV life-cycle, from PV production sites and inverter manufacturers to installers and recycling companies. The objective of those jobs is diverse and includes a wide range of positions and levels.

- Indirect jobs, indirectly associated with the PV industry by providing general components or services, e.g. raw material suppliers, production equipment, electrical devices and public officers for administration and taxes.

Evaluating the amount of jobs created by the PV industry, module manufacturing can generate 3-7 direct and 12-20 indirect jobs per MWp produced, depending on the technology. The rest of the jobs relevant to the installation of photovoltaics (e.g. civil workers, electricians, engineering, administration, etc.) are mostly localized around the customer. Half of these "new" employment opportunities are connected to the production phases, while the rest are connected to the installation phase of the PV chain [163].

For the case of Greece and according to a recent study quantifying the employment benefits associated with renewable energy technologies in Greece, high employment benefits, equal to 4.9 €/MWh, are detected for the case of PV industry, with the manufacturing phase contributing the most (76%) to the total employment benefits. One more interesting fact is that according to the same study, PV employment benefits are the highest compared to the rest of the RES technologies as well as to the lignite fuel cycle [164].

- **Security of energy supply**

According to the European Commission, the term "security of energy supply" can be defined as the "uninterrupted physical availability of energy products on the market, at a price which is affordable for all consumers, both private and industrial". Indeed, the three goals of every government are to provide its citizens with energy services that meet their needs steadily, affordably and environmental-friendly. However, this can be very challenging for both developed and developing economies, since the interests of the three aforementioned goals often collide with each other [165].

The main energy security risks that a country might face are [165]:

- The incapacity of the existing electricity infrastructure systems to meet the growing load demand;
- Energy market instabilities caused by unpredicted changes in geopolitical or other external factors, or compounded by fossil fuel resource concentration in specific regions of the world;
- Physical security threats of potential attacks on centralized power production structures, transmission and distribution grids or gas pipelines caused by terrorists, sabotage, theft or piracy, as well as natural disasters (earthquakes, hurricanes, volcanic eruptions, the effects of climate change etc.).

In contrast to conventional fossil fuels, solar photovoltaics represent a secure domestic source of clean energy with limited security risks from GHG emissions and climate change. This is a major benefit but very difficult to monetize. One more advantage of solar energy is its distributed nature, which makes it less vulnerable to power supply threats compared to central power infrastructure. The most common way of presenting quantitatively energy security benefits is in barrel of oil equivalents (BOE), where one BOE represents the energy released by burning a barrel of oil which corresponds to 1,700 kWh [166], [166].

Unfortunately, for the case of Greece the externalities related to the security of energy supply have not been estimated yet by any publication, according to our knowledge. However, it is important to emphasize on the fact that Greece imports all the oil and natural gas necessary to meet its energy needs. Considering that these imports account for more than 200 million barrels of oil equivalent on a yearly basis (including NG, electricity, etc.), we understand the deep dependence of the country on them, something that makes the security of energy supply externalities highly important [29].

- **Avoided fuel costs**

The implementation of PV technology can lead to a gradual reduction of conventional power plants, which is a great advantage for a country's economy considering the fuel costs of the operating thermal power stations that will eventually be avoided. The annual fuel savings attributed to the operation of PV power stations instead of conventional ones can be estimated with the equation below:

$$M_f = E_{PV} / \eta_d \cdot H_u$$

where:

- M_f : the annual amount of fuel savings
- E_{PV} : the energy produced by photovoltaics
- η_d : the efficiency of a typical thermal plant
- H_u : the corresponding specific calorific value of the fossil fuel consumed.

In the context of a social cost-benefit analysis the above savings are valued at the actual price of each fuel type for the calculation of the avoided costs of each technology.

For the case of Greece two types of avoided fuel costs should be taken into account: the ones resulting from the substitution of cheap indigenous lignite that are rather low, and the ones originating from the expensive imported natural gas and oil, which are significant due to the big dependence of the country on imported fossil fuels and their corresponding volatile prices [167].

- **Capacity Credit**

The term "capacity credit" assigned to solar technologies reflects the capacity of an alternative energy resource that can be displaced by including solar in a portfolio, without compromising the existing energy reliability levels. For example, a capacity credit of 50% for PV indicates that a 100 MW PV plant can contribute the same towards meeting peak load and planning reserve margin as a 50 MW conventional one. The capacity credit of solar energy is directly related to energy production and demand. More precisely for PV technology, it mainly depends on the configuration of the PV system (e.g. single-axis tracking PV vs. fixed PV) and the magnitude of energy demand during peak hours (e.g. summer afternoon peaking vs. winter night peaking). According to research, capacity credit decreases with increasing penetration of solar technologies. In the context of a SCBA, the capacity credit of a new PV plant is an important input as it demonstrates the level of avoided capital costs in new conventional power plants; thus it can be seen as a benefit of solar energy [168].

For the case of Greece, a few studies have been published examining the capacity credit of RES technologies in general. According to them, a typical capacity credit for PV power plants in the country is approximately 28%, as calculated based on the real data of the Greek power system of 2011 [169].

- **Costs for grid reliability**

As already mentioned, the primary concern of a power system operator is to supply electricity to its customers in a reliable and sustainable way. This involves ensuring that energy generation meets the demand at all times and that any possible gaps occurring are bridged properly to maintain the integrity of the power system. For this reason, many operators need to update their networks in order to cope with the inevitable challenge of high penetrations of renewables. This results in the generation of additional costs for each energy technology, such as the costs of building new or maintaining/upgrading the already existing infrastructure (transmission and distribution grids) as well as the costs of creating additional reserve capacities to compensate for the variability and unpredictability of those resources. Identifying these extra costs of grid reliability is obviously a complicated task and it depends on the abilities of the system operator to operate flexibly, with short interval dispatch, and to share reserve generation across a broader region. However, most of the times these costs are considered as part of the total investment costs of the power generating technology (i.e. have to be covered by selling the energy of the RES plant). For the case of Greece, whenever further reinforcement of the network is necessary, related costs are born by the Hellenic Transmission/Distribution System Operator and collected through the regular network charges. [42], [170].

To conclude for Greece and solar PV plants that are the main objective of the thesis, these costs can be considered insignificant, as they are already integrated in the total investment costs of the technology. Furthermore, the lack of research on this matter doesn't allow us to make other reliable estimations that can be used in the current analysis.

- **Regional Development**

Regional development in the areas where PV projects are implemented refers mainly to the direct or indirect employment created by the project. Concerning Greece, RES-electricity producers are subject to a special annual fee equal to 3% of the gross proceeds accrued from the sale of electricity generated by RES, which is collected by the Hellenic Transmission System Operator. Half of this levy is given to the local authority for the finance of local development projects, while the other half is directed to individual citizens of the relevant local communities and the Greek Fund for NATURA 2000 areas. However, large-scale PV power stations are excluded from it [42].

- **<u>Taxation fees</u>**

Standard welfare analysis describes tax payments as transfer payments not relevant to the Pareto efficiency. However, this can be argued considering that taxes create differences between the prices of goods and services and their social opportunity cost. Such differences in tax payments have the potential to create significant financial advantages and disadvantages among alternative fuel cycles as well, which means that they are related to Pareto efficiency and thus should be considered in a SCBA [171].

For the case of Greece, some researchers consider taxation as a source of financial benefits including both the annual tax paid on the basis of net cash flows and the provision of a fixed revenues' fraction to the municipality where the RES power station operates, while others distinguish them more clearly to benefits (Income tax and VAT) and costs (losses of public benefits due to reduction of employment) [167], [172].

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Chapter 6: Social Cost Benefit Analysis of large-scale PV technology in Greece

After the theoretical description of the Social Cost Benefit Analysis in the former chapter, it is time to proceed with the practical implementation of the method to evaluate the transition of large-scale PV power plants in Greece during the crisis, which is the main goal of the thesis. As already explained, to perform the final calculations of the SCBA, the analysis will be split in two distinct parts: the financial and the socio-economic (or economic) part. In the former part only the costs and benefits from the private investor's point of view are considered while in the latter all social aspects from the Greek society's point of view are taken into account.

In the beginning of the current chapter, a clear definition of the project under evaluation is performed. Firstly, the binding targets are set, based on the "20-20-20" targets of the European Union (March 2007), the Renewable Energy Directive 2009/28/EC and the National Renewable Energy Action Plan of Greece (2009). Secondly, the required PV capacity as well as the possible locations of the proposed PV plants are selected. Lastly, their annual performance and technical characteristics are defined.

Following the project's full identification, the financial analysis comes next. According to the financial parameters characterizing the Greek distorted economy, the discounted cash flow methodology is applied in order to calculate the Net Present Value (NPV) and the Internal Rate of Return (IRR) of the investment. Depending on the final results, the proposed project is designated as financially viable or not. Subsequently, the socio-economic analysis of the project takes place. All costs and benefits of large scale PV plants, including externalities, count. With a similar methodology the Social Net Present Value (SNPV) and the Social Internal Rate of Return (SIRR) are calculated, defining the overall viability of the proposed project.

It is important to mention that for both parts of the SCBA, a baseline scenario, where all parameters are given their most probable values, is being examined initially. However, after that a sensitivity analysis is performed to check how our results would be affected and how responsive these results would be to changes in the values of critical but uncertain variables. The chapter ends with a comparison between the findings of the financial and the economic CBA.

6.1 Definition of the Project

The purpose of the thesis is to examine whether the installation of large-scale PV plants in the Greek territory is a promising investment for the country and its people during the on-going crisis. However, in order to be able to judge this, the proposed project should be firmly defined.

Beginning to synthesize the project, the targets of the National Renewable Energy Action Plan (NREAP) published by the Greek government in 2009 will be our main reference. According to the aforementioned report, the solar PV capacity expected to be installed in Greece by the year 2020 varies, depending on three different scenarios: the Reference, the Compliance and the Accelerated Economic Recovery scenario. The Reference scenario is based on a pessimistic economical approach; thus only 700 MW of solar PV capacity are expected to be installed by 2020. The Compliance scenario is the one that ensures compliance with the EU's "20-20-20" obligations and suggests 2200 MW of solar PV capacity to be installed. Lastly, the Accelerate Economic Recovery scenario appears to be the most optimistic, defining 2900 MW of solar PV capacity to be installed. According to the statistical data of the Hellenic Association of Photovoltaic Companies, the total PV capacity installed in Greece in 2013 was equal to 2627 MW. As the corresponding capacity has already exceeded the estimations of the Reference and Compliance scenarios, our project will adopt the target set by the Accelerated Economic Recovery scenario, imposing 2900 MW of solar PV capacity to be installed in Greece by the end of 2020. Setting the project's target to 2900 MW and knowing that 2627 MW have already been achieved, we assume that the rest 273 MW are going to be covered only by large scale new-built PV power plants. We presume that the realization of the new PV installations will be distributed equally throughout the coming period of 5 years (2016-2020), resulting in the addendum of 54.6 MW/year of PV capacity to be installed to meet NREAP's target [42], [87].

When evaluating solar energy projects, the operating location of the PV plants affects directly not only the amount of energy produced but all costs and benefits deriving from the project. Thereby, our next step is to determine the location in which the new PV plants of our project will be placed. As argued in previous chapters, Greece shows great solar potential (figure 23) but it is also characterized by its special landform and topography. With the help of the information gathered from the interactive geographic map of the Greek Regulatory Authority for Energy (figure 26), we can conclude that the proposed new PV plants of our project will belong to one of the following categories:

- **“L-L” PV plants (Low solar potential, Low infrastructure cost)**

  Such PV plants are encountered in the mainland of Greece, mainly at northern regions where the solar potential is relatively low. Their typical capacity and energy yield varies, as it depends on the available land and solar potential respectively. Due to their proximity to the major road arteries and the existing electrical networks of the country, they have low infrastructure costs, making them a quite interesting investment in the recent crisis.

- **“H-L” PV plants (High solar potential, Low infrastructure cost)**

  These plants are installed in the mainland of Greece but in areas with high solar potential, mainly in the middle and southern part of the country. Their typical capacities vary, as in the “L-L” plants. However, due to their favorable location, they enjoy the privileges of high energy yield and low infrastructure costs at the same time, making them the most attractive investment of this kind.

- **“H-H” PV plants (High solar potential, High infrastructure cost)**

  These power plants can be found in islands, where the solar resources are usually rich. However, due to the special topography and limited land available in such regions, they are characterized by low PV capacities (usually < 1MW). They also have high initial investment cost and significant time of construction, as they require major upgrades of the electrical network and underwater connections. Thus they are considered as expensive and technically difficult projects.

Having defined the three specific types of PV power plants considered in our analysis, their realization-timeline should be set. As already stated above, our project will be held in 5 parts within the period 2016-2020, during each an even amount of 54.6 MW/year PV capacity will be added to the Greek territory. This additional PV capacity will be achieved by installing a mix of “L-L”, “H-L” and “H-H” PV plants per year. Due to the economic crisis still evident in the country, it is assumed that “L-L” and “H-L” plants will be realized first, as they constitute the most affordable ones, while the most capital intensive “H-H” plants will follow later. Table 15 below shows the exact allocation of the additional PV capacity from 2016 to 2020. The total PV capacity added per year represents one “sub-project” of the major “Project and it is assumed that each year one “sub-project” is completed. Its operation starts in the year following its construction, with a total lifespan of twenty years, from erection to disposal. Therefore, the economic lifetime of our major “Project” begins in 2016 with the erection of the first sub-project and ends in 2040 with the end of the last sub-project’s lifetime.

Table 15: Additional PV capacity per PV plant type & per year (MW). The total PV capacity added per year represents one "sub-project" of the major "Project".

Years	Additional PV capacity per PV plant-type & per year (MW)			
	"L-L"-type	"H-L"-type	"H-H"-type	TOTAL
2016	39.6	15	-	54.6
2017	15	39.6	-	54.6
2018	-	54.6	-	54.6
2019	-	50	4.6	54.6
2020	-	45	9.6	54.6
TOTAL ADDITIONAL PV-CAPACITY FOR 2016-2020				**273**

After defining the sub-projects in terms of additional PV capacity installed per year, we proceed with the calculation of their annual energy yield. To do so, the capacity factor (CF) of each type of PV park should be used. As already explained, the capacity factor of a PV plant is the ratio between the electricity it actually produces and the electricity it would produce, if it worked at nominal capacity for one year. Due to their high dependency on the location, capacity factors show a range of 10-25%. In the case of Greece, 46 different locations were examined in order to define the usual CP values of PV power plants operating in the country. According to the results, the minimum CP value was 19.4% in the region of Ioannina and the maximum 24.2% in the region of Tymbakion, with an average of 21.9% [86]. For the purposes of our study and based on the aforementioned values, the values of CP for each type of PV plant of our project, are summarized in the next table 16:

Table 16: Capacity Factors' Ranges & Mean Values for all types of possible PV plants in Greece (%) [86].

Project Type	Capacity Factor Range (%)	Mean Value (%)
"L-L" type	19 - 20	**19.5**
"H-L" type	21 - 25	**23**
"H-H" type	21 - 25	**23**

At this point, it is necessary to stress the importance of the CF value to our calculations. As already mentioned, the estimation of the annual energy yield and, consequently, all benefits deriving from the use of PV plants to generate electricity for both the private investors and the society as a whole, are directly associated with this factor. Consequently, the capacity factor will be one of the parameters varies in the sensitivity analysis in the sections following.

Returning to the calculation of the annual energy yield of the Project, this can be achieved with the use of the following equation:

$$CF = \frac{E}{P_{rated} \cdot 8760} = \frac{Y_f}{8760} = \frac{H_t \cdot PR}{P_{rated} \cdot 8760} \Rightarrow E = CF \cdot 8760 \cdot P_{rated}$$

From the above formula it is obvious that the annual energy yield is not a function only of the capacity factor (CF) but also of the performance ratio (PR). The latter term, as explained in chapter 4, quantifies the overall effect of losses on the rated solar energy output [82]. The losses that are being represented by the performance ratio along with a brief explanation of their causes are summarized in table 17 below:

Table 17: Losses of PV systems incorporated in the Performance Ratio (PR) [173].

Pre-Module Losses	**Tolerance of rated power**	Caused by the fact that the module does not deliver the power as stated in the data sheet. Manufacturers provide a tolerance, often up to 5%.
	Shadows	Shadows may be caused by trees, chimneys etc. Depending on the stringing of the cells, partial shading may have a significant effect.
	Dirt	Losses due to dirt can be equal to 4% in temperate regions with some frequent rain and up to 25% in arid regions with only seasonal rain and dust.
	Snow	Dependent on location and maintenance effort.
	Reflection	Reflection losses increase with the angle of incidence. Also, this effect is less pronounced in locations with a large proportion of diffuse light, i.e. clouds.
Module Losses	**Conversion**	The nominal efficiency is given by the manufacturer for standard conditions.
	Thermal losses	With increasing temperatures, conversion losses increase. These losses depend on irradiance (i.e. location), mounting method (glass, thermal properties of materials), and wind speeds. A very rough estimate is ~8%
System Losses	**Wiring**	All cables have some resistance and therefore losses.
	MPP	Ability of the MPP tracker to consistently find the maximum power point.
	Inverter	Refers to losses due to the inverter.
	Mis-sized inverter	If the inverter is undersized, power is clipped for high intensity light. If it is oversized, the inverter's efficiency will be too low for low intensity light.
	Transformer	Transformer losses in case electricity has to be connected to a high-voltage grid.

As today's PV systems show typical performance ratios between 80-90%, for the purposes of our Project a PR equal to 90% is considered.

Taking into account all of the aforementioned factors, the annual amount of energy added to the Greek energy mix per year during the period 2016-2020 is calculated and presented in table 18:

Table 18: Annual addition of solar PV energy in Greece for the period 2016-2020.

Years	Annual Energy Addition per PV plant-type (MWh)			
	"L-L"-type	"H-L"-type	"H-H"-type	TOTAL
2016	60880.248	27199.8	0	88080.048
2017	23060.7	71807.472	0	94868.172
2018	0	99007.272	0	99007.272
2019	0	90666	8341.272	99007.272
2020	0	81599.4	17407.872	99007.272
TOTAL ADDITIONAL ENERGY FOR 2016-2020				479970.036

However, there is one more parameter that should be depicted in our SCBA; the degradation of the PV systems. The degradation of a PV system refers to its subsequent loss of performance and is caused by its inevitable natural decay. Due to the fact that over its long lifetime the efficiency reduction of a PV system can be significant, a degradation rate of 0.5%, implemented after the year of erection, will be considered for the calculation of the annual energy yield during the lifespan of each sub-project, which will follow in the next sub-section [174].

6.2 Financial CBA

After having defined the initial aspects of the Project, we move on to the conduction of the financial CBA calculations. Since the installation and operation of the PV parks will be undertaken by private investors, performing a financial CBA from their point of view is very important, as it will indicate whether the proposed investment is profitable for them or not. Generally, for the financial assessment of an investment several indicators can be used, with most common the Net Present Value (NPV), the Internal Rate of Return (IRR), the Discounted Payback Period (DPP) and the Levelised Cost of Energy (LCOE). In our case, the NPV and the IRR will be used to evaluate the financial viability of the sub-projects needed for the country to reach its solar PV energy targets by 2020 [175].

To proceed further, the following assumptions are made:

- The whole Project, consisting of the five sub-projects elaborated before, is undertaken by a single private investor.
- The Project's capital is partially provided by the private investor and partially through loans issued by the Greek banks.

Since the theoretical concepts of the NPV and the IRR have been explained in chapter 5, the step-by-step methodology, containing all the equations necessary for our financial CBA, will be presented in the next section.

To begin with, the NPV of an investment refers to its value discounted at the time of commencement of its commercial operation and it is calculated by the following equation:

$$NPV = -C_0 + \sum_{t=1}^{N} \frac{NCF_t}{(1+k)^t} + \frac{SV_N}{(1+k)^N}$$

where:

- C_0 : the initial cost of the investment
- NCF_t : the Net Cash Flow of year t
- k : the discount rate
- N : the lifetime of the investment and
- SV_N : the salvage value of the investment in year N

After applying the above formula, if the calculated NPV result is positive, the investment should be realized and if it is negative, it should be abandoned. In the event of NPV=0, the acceptance or rejection of the investment is irrelevant for the private investor [175].

The IRR is the value of the discount rate that makes the NPV of the investment for the duration of the economic evaluation equal to zero. Therefore, the IRR of the investment can be estimated by the following formula:

$$NPV = 0 \Rightarrow -C_0 + \sum_{t=1}^{N} \frac{NCF_t}{(1+k)^t} + \frac{SV_N}{(1+k)^N} = 0$$

Regarding the calculated results, if the IRR is greater than the minimum required rate of return on investor's capital $(k_{\min Eq})$, the investment should be accepted while if it is negative it should be rejected. In the event of $IRR = k_{\min Eq}$, the acceptance or rejection of the investment is irrelevant for the private investor [175].

The evaluation of investments utilizes the concept of Net Cash Flows (NCF). In general, the NCF of each year is the difference between the cash inflows and outflows of the investment under examination. For solar energy projects the cash inflows are the revenues from selling the produced energy and the cash outflows include various operating cost components, as well as payments of income tax. For the sake of uniformity throughout our calculations, the following notation will be adopted, with respect to the financials of each year t [175]:

- R_t : the revenues from selling the produced energy
- OC_t : the operational costs of the investment, including O&M costs
- D_t : the depreciation expenses
- TR : the tax rate relevant to the taxation of income
- T_t : the income taxes paid by the private investor
- L_t : the loan payment, in case of borrowed funds
- I_t : the interest payment, in case of borrowed funds
- P_t : the principal payment, in case of borrowed funds

At this point, it should be noted that calculating the NCF and NPV of an investment gives different results, depending on whether the calculations are made with respect to the whole investment cost or just to the share of own capital in case of borrowed funds. More precisely, in the first case the interest and principal payments of the loan are not incorporated in the estimation of the NCF, while in the latter they do appear as cost components. Moreover, in an assessment of own share of capital, the discount rate used for the calculation of the NPV by the investor reflects what he considers to be the minimum acceptable rate of return on his own capital. On the contrary, in a financial evaluation as to the whole capital, the discount rate should be the weighted average cost of the total invested capital, which is composed by the cost of both equity capital and borrowed funds [175].

For the purpose of the current analysis, we choose to evaluate our Project in relevance to the investor's own funds and consequently the annual Net Cash Flow is given by the following equation [175]:

$$NCF_t = R_t - OC_t - T_t - L_t = R_t - OC_t - T_t - I_t - P_t$$

The calculation of interest (I_t) and principal (P_t) of the above formula differs depending on the method of loan repayment applied. In our case, an amortized loan will be considered; thus the loan repayment of year t is equal to the sum of the interest due on the outstanding loan balance, and the rest of the payment aiming in reducing the outstanding loan balance, otherwise known as the principal payment, as shown in the equation below [175]:

$$L_t = I_t + P_t$$

Assuming that the annual loan installments are fixed and done at the end of each year, it is observed that as time goes by the interest decreases while the principal increases. As far as the principal payment of each year is concerned, it can be calculated with the help of the next formula [175]:

$$P_t = \frac{k_l}{(1+k_l)^{N_l}-1} \cdot K_l \cdot (1+k_l)^{t-1}$$

where:

- k_l : the loan interest rate
- N_l : the repayment period of the loan in years
- K_l : the loan capital

The annual installments (L_t) of our amortized loan, as already mentioned above, are equal for every year and can be estimated from the following equation [175]:

$$L_t = (k_l + \frac{k_l}{(1+k_l)^{N_l}-1}) \cdot K_l$$

Based on the former relation, the interest payment of each year can be calculated with the next simple subtraction [175]:

$$I_t = L_t - P_t$$

The annual income taxes paid by the investor of the Project are determined by deducting from the Project's gross revenues the operating costs, the depreciation expenses and the interest payment. In other words, taxes are given by the formula [175]:

$$T_t = (R_t - OC_t - D_t - I_t) \cdot TR$$

Regarding the calculation of the annual depreciation of the new installations, we consider the linear or straight line method, which depreciates cost evenly throughout the useful lifetime of the investment. Therefore, the following relation applies [175]:

$$D_t = \frac{C_0}{N}$$

Based on all of the aforementioned equations, the calculation formula of the Net Cash Flow takes the following final form [175]:

$$NCF_t = (R_t - OC_t - D_t - I_t) \cdot (1 - TR) + D_t - P_t$$

Since the final equation and all parameters that will be used to calculate the Net Cash Flow have been established, it is time to proceed with the estimation of the NPV and IRR of the Project. This can be achieved by assuming either nominal or real values for the costs, the benefits, the discount and the interest rate. The difference between these two assumptions is explained below.

Conventional private-sector financial analysis mainly uses the nominal or current units of the cash flows. In this case, all costs and benefits are expressed in money terms of the year of realization by using the corresponding inflation rate and are discounted by using the nominal discount rate. The same applies for the calculation of loan installments, which should be based on the nominal interest rate, if a loan was acquired. Instead, public policy analysis uses real values for the cash flows with projected costs and benefits measured at today's prices. Real cash flows adjust for inflation; in fact, they constitute nominal values deflated by a price index in order to account for changes in the general price level [111], [176].

It should be noted that the units of measurement of costs and benefits should be consistent with the units of measurement of the discount and interest rate, in order to avoid possible mistakes. In other words, if costs and benefits are measured in nominal terms, then nominal discount and interest rates should be considered, while if measured in real terms, then real discount and interest rates should be applied. Needles is to say that no matter which method is adopted, the final result of the NPV should be the same [111].

Concerning our Project, the method of real values will be used, as it allows us to do our calculations without worrying about the future course of inflation, something that would make our job more complicated, due to the variation of inflation along the years. The equation giving the real discount and interest rate is the following [111], [176]:

$$r = \frac{i - m}{1 + m}$$

where:

- r : the real discount or interest rate
- i : the nominal discount or interest rate
- m : the inflation rate

After getting acquainted with the equations involved in the NPV and IRR calculation, we have to adjust them to the parameters of our own Project. As already mentioned, the Project consists of five new sub-projects, each of them expected to be realized at the beginning of each year of the period 2016-2020. This means that investment costs should be considered not only for 2016 but for all five years up to 2020. Similarly, the salvage value of the Project appearing at the end of the twenty-year lifespan of each of the installed sub-projects, should be included for all sub-projects; from the first one built in 2016 to the last one built in 2020. Lastly, the final calculated NCF of the Project should be the sum of the NCFs of all operating sub-projects, which in their turn consist of a unique mixture of "L-L", "H-L" and "H-H" PV plants for every year. Implementing all of the aforementioned parameters, the final equations for the calculation of the NPV and IRR of the project will take the following final form:

$$NPV = \sum_{t=1}^{N} \left(\frac{-C_{own,s,t}}{(1+k)^t} + \frac{NCF_{s,t}}{(1+k)^t} + \frac{SV_{s,t}}{(1+k)^t} \right)$$

and

$$\sum_{t=1}^{N} \left(\frac{-C_{own,s,t}}{(1+IRR)^t} + \frac{NCF_{s,t}}{(1+IRR)^t} + \frac{SV_{s,t}}{(1+IRR)^t} \right) = 0$$

where:

- N : the lifetime of the Project, equal to 24 years
- s : the number of sub-projects, taking values from 1 to 5.
- $C_{own,s,t}$: the own capital invested for the realization of sub-project s in year t, as a sum of the investment costs of all types of PV plants consisting the subproject
- $NCF_{s,t}$: the NCF of sub-project s in year t, as a sum of the $NCFs$ of all types of PV plants consisting the subproject
- $SV_{s,t}$: the salvage value of the sub-project s in year t, as a sum of the salvage values of all types of PV plants consisting the subproject
- k : the minimum required return on own capital invested, known as discount rate.

At this point, we need to assign numerical values to all inputs of the Project in order to proceed with the estimation of NPV and IRR. All relevant calculations will be executed in Microsoft EXCEL by creating the corresponding spreadsheets. It should be noted that all financial indicators considered in the subsequent calculations, constitute the most recent data available for the Greek sectors of solar PV and banking during the period of the crisis and were obtain after consultation with reliable sources.

We begin with defining all certain input parameters of the Project, which are identical for all types of PV plants considered. These values are kept the same for all of the different scenarios evaluated and are the following:

- The lifetime of each new-built PV plant is twenty years.
- The annual operational cost (*OC_t*) of each PV plant is considered to be 2% of its initial investment cost (*C_0*).
- The tax rate (*TR*) imposed on the private investor's annual income is 26%.
- The salvage value (*SV*) of each sub-project at the end of its operational life consists 15% of its total investment cost (*C_0*).
- The depreciation rate for the estimation of the annual depreciation expenses is considered equal to 5%.
- No subsidies apply to our Project, since the Greek state abolished this measure due to the financial crisis.

Subsequently, the calculation of the annual (gross) revenues (R_t) of the Project is performed. To do so, the annual energy production of each type of PV plant is added and multiplied with the proper feed-in tariff, according to the relevant support scheme presented in the latest National Law regarding RES development. The corresponding relation is the following:

$$R_t = (FIT) \cdot \sum_{t=1}^{N} E_{produced,t}$$

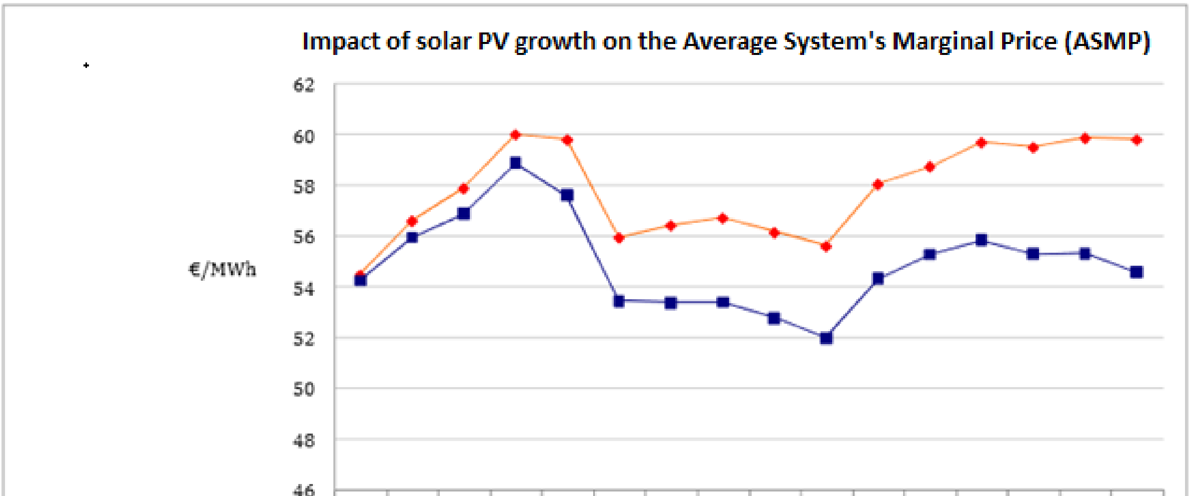
Regarding the feed-in tariffs applicable to large-scale PV parks, a first reference was made in Chapter 3. According to the parameters stated in table 6, the appropriate value of the feed-in tariff that should be used in our calculations can be selected. As all types of the proposed large-scale PV parks consisting our Project have capacity > 100 kW, are interconnected systems and are erected after 2015, the proper feed-in tariff is given by the relation (category A of table 6):

$$FIT = 1.1 \cdot ASMP_{n-1}$$

where $ASMP_{n-1}$ is the Average System's Marginal Price in the previous year n-1.

The term Average System's Marginal Price (ASMP) refers to the price at which the electricity market is liquidated. In other words, it is the price received by all those who inject energy into the energy system and the one paid by all those who consume it. The ASMP is determined by the price bids submitted by all available power plants for a specific quantity of energy in combination with the electricity load demanded by the consumers on a daily basis [177]. Consequently, the feed-in tariffs for the large scale PV stations are not constant but rather depend on the previous year's average system marginal price. This inserts one more difficulty in our analysis, as the exact values of the Greek ASMP up to year 2040 are not available. To overcome this issue, we have to base our assumptions on predicted data for the period under consideration. Taken from a relevant study, figure 40 depicts the impact of solar PV growth on the calculated ASMP for the period 2015-2030. From this graph, it can be seen that the fluctuation among the expected values of the ASMR is quite small, in a range between 52-59 €/MWh. For our calculations, due to the lack of sufficient data on the ASMP, we choose to consider the ASMP value constant for every year till 2040. Based on the values shown in figure 40 referring to new PV systems, we assume their mean value for the calculation of ASMP, which is equal to 55 €/MWh, as a constant input for the whole lifetime of our Project. Therefore, the feed-in tariff for all of the large-scale PV power plants included in our study is equal to:

$$FIT = 1.1 \cdot ASMP_{n-1} = 60.5 \text{ €/MWh}$$



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Without new PV systems	54,46	56,59	57,88	60,00	59,79	55,94	56,42	56,71	56,14	55,60	58,05	58,74	59,69	59,49	59,86	59,80
With new PV systems	54,25	55,94	56,85	58,87	57,61	53,42	53,37	53,40	52,79	51,98	54,32	55,27	55,83	55,28	55,31	54,57

Figure 40: Impact of solar PV growth on the ASMP predicted for Greece in years 2015-2030 [178].

At this point all certain parameters of our Project are established; thus we continue with the definition of all uncertain ones, which depend on the specific type of each PV plant considered in our Project. These values are the capacity factors (CF) and the investment costs (C_0). Regarding the Capacity Factors of each type of PV power plant proposed, table 16 already presents a summary of the ranges as well as the most probable values that are being used in our calculations. Due to the high solar potential of the country, it is obvious that the variation in CFs depending on the type of project is not that significant. Regarding the investment costs, the type of PV parks installed in the mainland require lower initial capital in comparison to the ones built on the islands. After personal consultation from Greek experts in the field of solar PV energy, table 19 summarizes the most probable investment cost ranges applicable to all different types of PV parks of our Project as well as their mean value, which is the one used in our calculations further:

Table 19: Investment Cost Ranges & Mean Values for all types of possible PV plants in Greece.

Project Type	Investment Cost (€/kW)	Mean Value (€/kW)
"L-L" type	900-1100	**1000**
"H-L" type	900-1100	**1000**
"H-H" type	1100-1500	**1300**

The annual investment costs of the Project are derived as the sum of the results of the multiplication of the investment cost of each PV plant type with its added capacity in that year's sub-project, as calculated previously. This reasoning is better described with the following formula:

$$C_{0,t} = \sum_{s=1}^{3} C_{0,s} \cdot EC_s$$

where:

- $C_{0,t}$: the annual investment costs of each sub-project
- $C_{0,s}$: the investment costs of each type of PV power plant
- EC_s : the energy capacity of each type of PV power plant

Establishing the financial parameters involved in the calculation of the Project's NPV and IRR comes next. These parameters are the share of the private investor's own capital, the inflation rate, the interest rate and the discount rate. All of the aforementioned inputs constitute uncertainties, and as such, their impact on our final results will be checked through sensitivity analysis. However, their most probable values as well as the ranges considered in the sensitivity analysis will be elaborated in the following section.

In the absence of subsidies or any other support scheme foreseen by the Greek government, the Project will be funded partially by the private investor's own capital (C_{own}) and partially by loan capital (K_{loan}), as shown by the following equation:

$$C_{0,t} = C_{own,t} + K_{loan,t}$$

The loan is assumed to be issued annually from 2016 to 2020 and its repayment period is considered equal to ten years. It is important to state that the financial crisis has taken its toll in the Greek banking sector as well. Consequently, Greek banks approve very few loans with the intention to cover a small share of the total investment, ranging between 20% - 60%. As already mentioned, this parameter will be checked with a sensitivity analysis for 20%, 40% and 60% of loan share (corresponding to 80%, 60% and 40% of private investor's own share respectively), while the most probable value used for our baseline scenarios will be 40%.

Moving on to the interest rate's calculation, the data usually quoted by banks, credit cards, stock brokers, etc. are in nominal values. As already explained, the nominal interest rate is the interest rate incorporating not only the cost of capital but also inflation and it is used to discount actual, inflated future values. By subtracting inflation from the nominal interest rate, the "real" earnings on an investment are left, in other words the real interest rate. The real interest rate should be used to discount future values that are expressed in real, deflated future values. For our calculations, as all data referring to the interest rate are retrieved in nominal values but we have chosen to work with real ones, the inflation rate should be defined in order to proceed [179].

The inflation rate, given as a percentage, indicates the rise in price of a good or service over a period of time. It is usually measured on a monthly or yearly basis. Inflation can be estimated with the use of various inflation indicators, among which Consumer's Price Index (CPI) is the most commonly used. To be more precise, CPI is a measure of the average change over time in the prices paid by urban consumers for a market basket of consumer goods and services. The term "market basket" is used to describe standard collections of goods, updated over time to reflect changes in technology, consumption and production patterns. The opposite of inflation is deflation, indicating a decrease in the general price level for goods and services [179], [180].

The inflation data required for our calculations were based on Trading Economics' global macro-model forecasts for the period 2016-2020 and the opinion of Greek experts on the field. Trading Economics' forecasts were made by modelling the past behavior of the Greek inflation rate and by adjusting the coefficients of these models, based on their analysts' assessments and future expectations. However, although the inflation rates for the period 2016-2020 are sufficient, predictions for the period 2020-2040, that refers to the whole lifetime of our Project, couldn't be found. After consultation with the Greek experts on the field, we assume that from 2020 to 2040 the inflation will remain constant with a mean annual value of 2.6%. Table 20 summarizes the Greek inflation rates taken into account in our calculations for the period 2016-2040 [181], [182], [183]:

Table 20: Greek Inflation Rate Forecast 2016-2040 [181], [182].

Years	2016	2017	2018	2019	2020-2040
Inflation (%)	0.4	1.1	1.8	1.9	2.6

Despite knowing the annual inflation rates for each sub-project of our analysis, the calculation of the NPV and IRR of the whole Project requires the estimation of the inflation rate over the whole period of the Project's lifespan. This can be achieved with the use of the following equation:

$$m = \left[\sqrt[(t_{last} - t_{first})]{\frac{CPI_{last}}{CPI_{first}}} - 1 \right]$$

where:

- t_{first}, t_{last} : the first and last year of the lifetime of the Project
- $CPI_{first,} CPI_{last}$: the CPIs for the first and last year of the lifetime of the Project

In Greece, the Consumer's Price Index is officially recorded by the National Statistical Service of the country. It can be briefly mentioned that the Greek CPI showed an average of 39.82 Index Points in the period 1959 -2016, reaching an all-time high of 111.34 in 2012 and a record low of 1.14 in 1959. In 2016, which is the first year of our Project, the value of CPI is estimated to be equal to 104.15 Index Points [181]. Having the CPI value of 2016 as a starting point and knowing by definition that the annual inflation rate for a given year is the percentage change from the previous year, we are able to calculate the CPIs from 2016 to 2040, in order to estimate the inflation rate of the Project as a whole. The results are gathered in table 21 below:

Table 21: Estimated Consumer's Price Index for the period 2016-2040 in Greece.

Years	2016	2017	2018	2019	2020-2040
CPI	104.150	105.296	107.191	109.228	112.068

Subsequently, the average annual inflation rate over the period of the Project's lifetime, which coincides with the period of financial evaluation, is:

$$m=\left[\sqrt[(t_{last}-t_{first})]{\frac{CPI_{last}}{CPI_{first}}}-1\right]\cdot 100\%=\left[\sqrt[(2040-2016)]{\frac{112.068}{104.150}}-1\right]\cdot 100\%=0.3058\%$$

One more financial parameter to be defined is the interest rate of the loan, which along with the private investor's own share of capital is considered as a partial means of funding of the Project. This interest rate belongs to the uncertain inputs of our calculations and is affected by the crisis the country is currently facing. In general, it is observed that interest rates rise during a financial crisis and decrease in times of relative financial stability and political tranquility. For our calculations, we choose to work with the interest rate set by the National Bank of Greece, which is the biggest bank of the country and therefore it is considered as the most credible one. The interest rate relevant to our analysis is the one offered for secured personal loans, which is equal to 6.318% [184]. Since the aforementioned interest rate is nominal, it needs to be converted to a real value, as shown below:

$$k_{l,real}=\frac{k_{l,nominal}-m}{1+m}=\frac{6.318-0.3058}{1+0.3058}=4.6\%$$

The above calculated value of the interest rate is the one to be used for our baseline scenario and every other scenario occurring from the variation of other key parameters. As already mentioned, the interest rate is an uncertainty, and as a result, its impact on our final calculations will be checked through a sensitivity analysis. Considering the country's ambiguous financial state, the interest rate possible values that will be taken into account in the sensitivity analysis will range between 3.6% - 5.6%.

The last parameter that needs to be defined for the calculations of the Project's NPV and IRR is the discount rate. This financial indicator is the opportunity cost of capital and reflects the loss of income from an alternative investment with a similar risk profile. There are many theoretical and practical approaches on selecting the discount rate appropriate for each financial analysis. Among them, the most accurate is to consider the return lost from the best alternative investment and based on that to determine the maximum limit value for the discount rate. For the purposes of our analysis, we consider deposits paid by the National Bank of Greece to non-financial corporations as the risk-free alternative to our Project. At this point it should be mentioned that the interest rates vary depending on the maturity of the deposit. However, for deposits exceeding one year of maturity, which would be more representative due to the Project's long lifetime, the corresponding data is not available for confidentiality reasons. Due to the lack of such information, the interest rate for one-year time deposit accounts will be considered for our calculations, as published by the National Bank of Greece in March 2016, which is equal to 1.79%. Since this value is nominal too, it needs to be converted to a real one, by using the same formula for inflation as before [145], [185], [186], [187]:

$$k_{real} = \frac{k_{nominal} - m}{1 + m} = \frac{1.79 - 0.3058}{1 + 0.3058} = 1.14\%$$

The interest rate paid by banks or the bond yields paid by governments constitute risk-free investments, and as such, they represent the lower limit of the range of possible discount rates that can be considered in a project. However, from the private investor's point of view, the discount rate should account for all other alternatives for investment as well as for all risks associated with the project under evaluation. Consequently, private investors usually consider a discount rate that is significantly higher than the interest rates given by banks or governmental bonds. In our case, in addition to the risks mentioned before, the risk employed by the Greek financial crisis should also be reflected in the correct selection of the Project's discount rate. For all the above mentioned reasons, the previously calculated discount rate will be increased by 1%-3% in order to be used in our NPV and IRR analysis. This means that for our project the range of possible discount rate scenarios is 2.14% - 4.14% with a mean value of 3.14%. Similar to the interest rate, the real discount rate of 3.14% is the value used for the baseline scenario and every other calculation that involves the variation of other key parameters, while the minimum and maximum values of 2.14% and 4.14% respectively will be checked through a sensitivity analysis [145], [185], [186].

The previously chosen discount rates are also confirmed by the European Commission, which is important since the Project can be considered as a possible EU's investment. According to the Commission Delegated Regulation (EU) No 480/2014 for the programming period 2014-2020, the European Commission recommends a real discount rate of 4% to be considered as the reference parameter for the real opportunity cost of capital in the long term, to ensure consistence between all EU Member States. Values differing from the 4% benchmark may, however, be justified on the grounds of international macroeconomic trends and conjunctures, the Member State's specific macroeconomic conditions and the nature of the investor or the sector concerned. Therefore, for the case of Greece, the average value we use is lower than 4%, in order to reflect the financial crisis, that the country is currently facing [145].

After establishing all of the certain and uncertain financial parameters that are going to be used for the calculation of the NPV and IRR of the Project from the private investor's side, a summary of them can be found in table 22:

Table 22: Summary of all financial parameters for the calculation of the NPV & IRR of every scenario of the Project.

Parameters		Types of PV Power Parks		
		"L-L"	"H-L"	"H-H"
Certain	Lifetime (years)	20		
	O&M Costs (% of the investment cost)	2		
	Tax Rate (%)	26		
	Salvage Value (% of the investment cost)	15		
	Depreciation Rate (%)	5		
	Annual PV System's Degradation Rate (%)	0.5		
	Subsidies (€/MWh)	-		
	Feed-In Tariffs (€/MWh)	60.5		
	Annual Inflation Rate (%)	0.3058		
Uncertain	Capacity Factor (%)	19 - 19.5 – 20	21 – 23 - 25	21 – 23 – 25
	Investment Cost (€/kW)	900-1000-1100	900-1000-1100	1100-1300-1500
	Loan Percentage (%)	20 – 40 – 60		
	Real Interest Rate (%)	3.6 – 4.6 – 5.6		
	Real Discount Rate (%)	2.14 – 3.14 – 4.14		

Introducing the above mentioned financial parameters in the final equation forms of the NPV and IRR presented previously, the NPV and the real IRR of the Project for all possible scenarios are calculated. The main scenarios examined are the baseline, the minimum and the maximum scenario. For the calculations of the former, the standard values of the certain as well as the most probable values of the uncertain parameters are taken into consideration. For the calculations of the rest, the values of the parameters known with certainty as well as the minimum and maximum values of the uncertain ones are considered respectively. More simply stated, a partial sensitivity analysis is conducted, considering the lowest and highest values of every uncertain parameter for the recalculation of the NPV and the real IRR, while keeping the rest of the parameters constant at their certain (for certainties) or most plausible (for uncertainties) value. All of the required calculations were executed through Microsoft Excel and the numerical results are presented in detail in Appendix A. The graphical results of our calculations are depicted in figures 41 and 42 that follow. More specifically, figure 41 shows the estimated findings of the NPV, while figure 42 the ones of the real IRR with respect to the aforementioned scenarios.

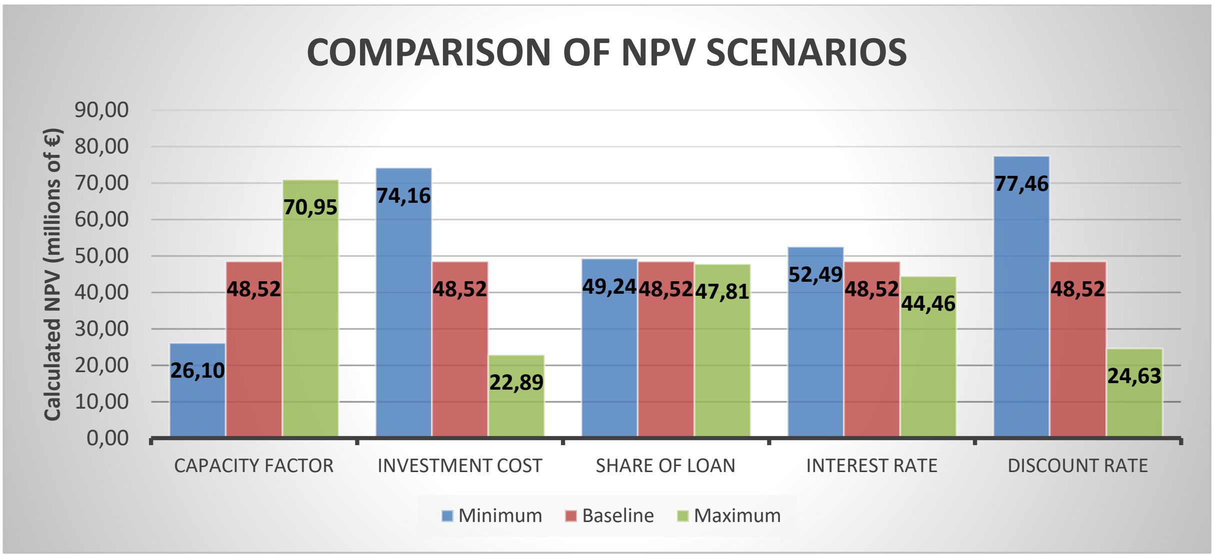


Figure 41: Private CBA Sensitivity Analysis Results – Comparison of the calculated NPV per uncertainty and scenario.

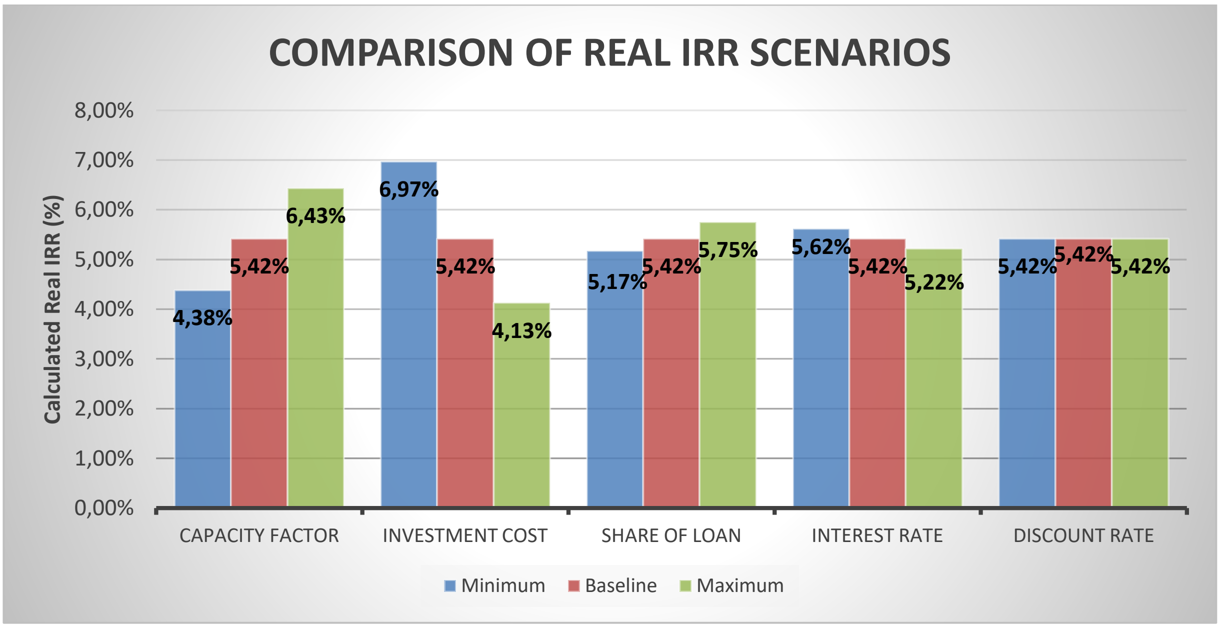


Figure 42: Private CBA Sensitivity Analysis Results – Comparison of the calculated Real IRR per uncertainty and scenario.

The results of the NPV and IRR calculations, as presented in Appendix A as well as in the figures 41 and 42, bring us to the conclusion that the proposed Project is an attractive investment and should be undertaken by the private investor. This positive outcome is based on the fulfillment of the following two criteria:

- **NPV > 0**

  The calculated NPV value for all plausible scenarios examined in the sensitivity analysis is positive. This indicates that the investor will gain more profit by accepting the proposed Project under all circumstances rather than investing the same amount of money in Greek bank's deposits.

- **Real IRR > Real Discount Rate**

  The estimated values of the real IRR range between 4.13% - 6.97% for all possible scenarios of the sensitivity analysis. Since the real IRR exceeds in every case the private investor's required rate of return, which is assumed equal to 3.14%, the proposed Project is lucrative for the investor and thus worth undertaking. Despite the profitability of the Project, the presence of the financial crisis in the country is evident at the IRR calculations, as the difference between the calculated IRR values and the private investor's rate of return is not so great.

Elaborating more on the results of our calculations, it can be stated that the discount rate, the investment cost and the capacity factor have the greatest influence on the calculated NPV value, in contrast to the interest rate and the share of loan that have the lowest. Similarly, for the case of the IRR, the investment cost and the capacity factor play the most crucial role, while the share of loan along with the interest rate are of moderate importance. The changes in the discount rate bare no impact on the calculated IRR, as implied by the definition of the term and can be confirmed by the corresponding IRR equation presented previously.

Furthermore, it can be observed that for all of the uncertain parameters considered, the NPV and IRR vary following a similar pattern; a parameter that causes an increase in NPV, causes an increase in IRR and vice versa. However, there is one exception; the share of loan (or share of own capital) provides conflicting results between the NPV and the IRR, in a way that one scenario may have a higher NPV but a lower IRR value compared to the corresponding values of another one. This conflict is usual when comparing mutually exclusive scenarios and occurs due to the different initial investment and cash flow patterns between them. To prevent a possible confusion in the process of decision making, it is preferred to rely on the NPV rule whenever those two values are inconsistent, as it reflects better the profitability of the examined project to the private investor.

Examining the minimum, baseline, and maximum scenarios of each uncertain financial parameter offered us an important overview of the Project's lower, middle and upper profitability limits. However, for a deeper understanding of their impact on the NPV and IRR calculation, we need to study further the response of the NPV and IRR as each of the aforementioned parameters takes values within its possible range. In other words, we need to determine the NPV and IRR values as a function of each uncertain parameter. This can be achieved by assigning different values within the available range of each parameter, while keeping the rest of the inputs constant. The graphical depiction of the consequent NPV and IRR numerical results that aroused from this procedure can be seen in figures 43 and 44, for the NPV and IRR respectively:

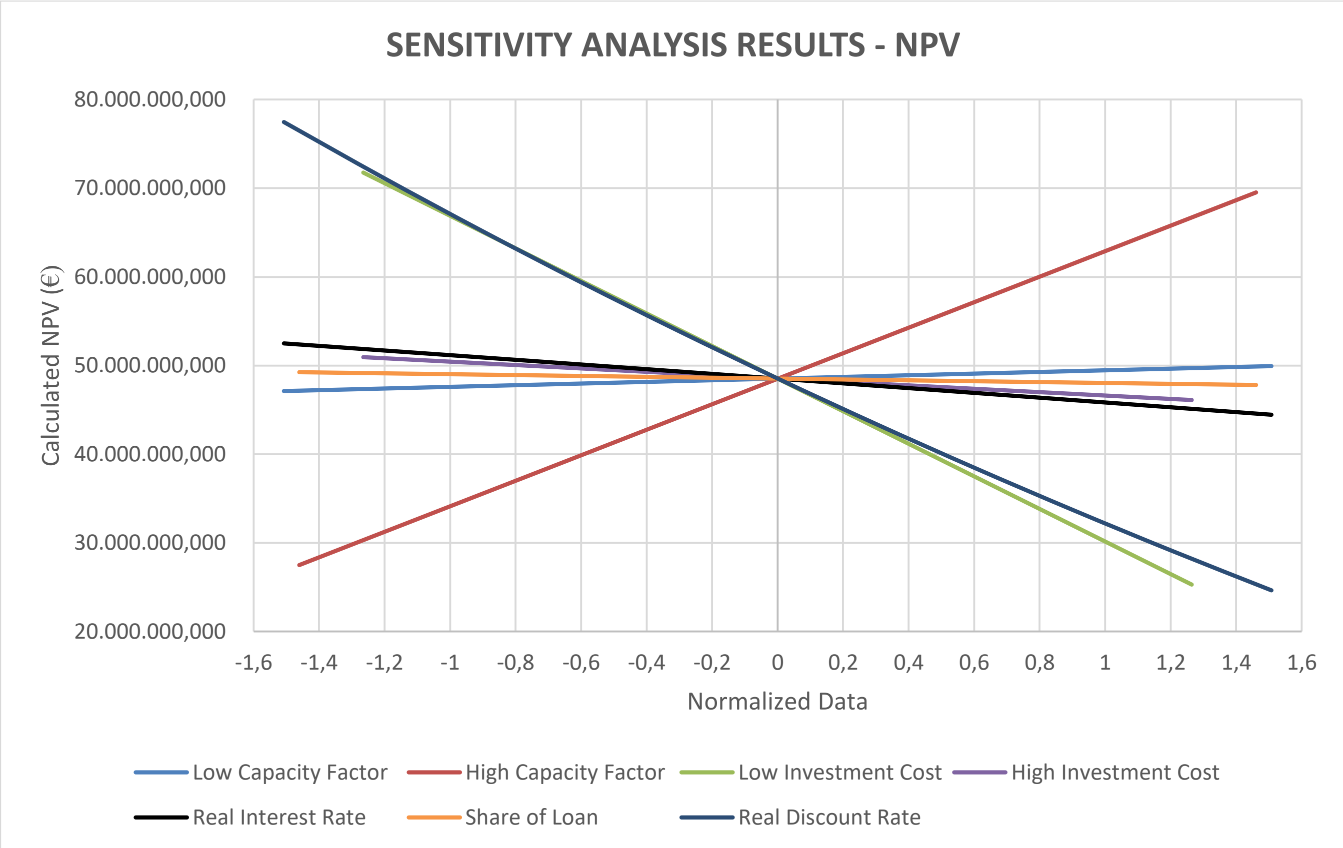


Figure 43: Private CBA Sensitivity Analysis Results – All Uncertain Financial Parameters VS NPV.

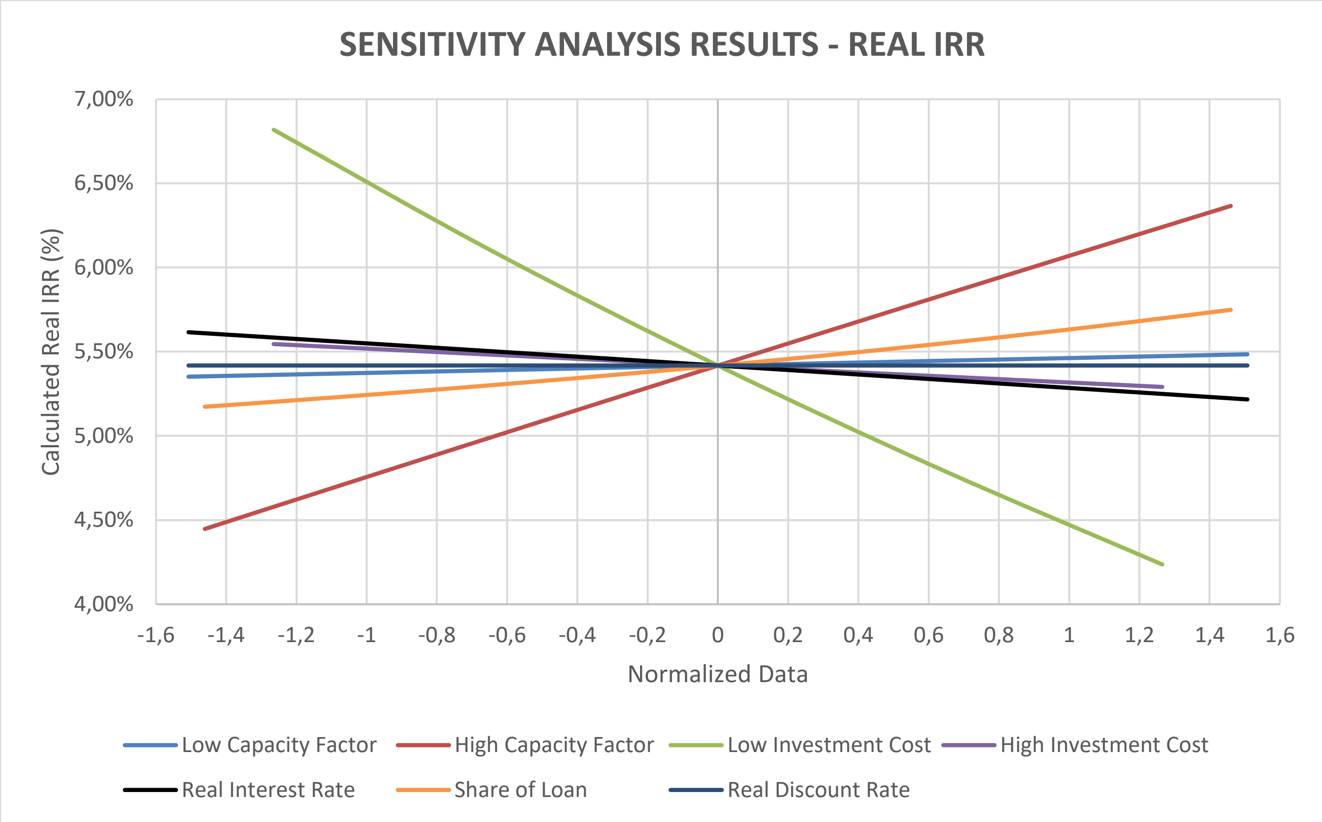


Figure 44: Private CBA Sensitivity Analysis Results – All Uncertain Financial Parameters VS Real IRR.

Regarding the figures 43 and 44, for the sake of a fair comparison, all uncertain parameters had to be projected together in the graphs, regardless of their units of measurement, which were of course different. This step is very important when dealing with parameters of different units and scales to enhance the comparison process. For this reason, before the creation of the diagrams, the available data was standardized with the help of Microsoft Excel. During this process, all uncertain parameters were checked independently of one another, in order to determine which of them had the biggest impact on the Project's NPV and IRR calculated values. From the above figures it can also be noted, that the relation between the uncertain parameters and the NPV and IRR is rather linear.

Table 23 below, briefly summarizes all uncertainties and their impact to the final calculations of the NPV and IRR, from the most to the least influential ones, as emerged from the sensitivity analysis of the Project. Furthermore, in the following section each parameter and its effects on the calculation of both financial indicators is commented in more detail.

Table 23: Summary of the influence of all uncertain parameters to the NPV & IRR calculations, presented from the most to the least significant one.

Financial Indicator	NPV		IRR	
Relation	Linear & Proportional	Linear & Inversely Proportional	Linear & Proportional	Linear & Inversely Proportional
Parameters	High Capacity Factor	Real Discount Rate	High Capacity Factor	Low Investment Cost
	Low Capacity Factor	Low Investment Cost	Share of Loan	Real Interest Rate
	Share of Loan	Real Interest Rate	Low Capacity Factor	High Investment Cost
	-	High Investment Cost	-	-

To begin with, the most influential parameter among all uncertainties examined was the investment cost. However, this outcome was expected, since the installation of a PV power plant constitutes a capital-intensive venture. More precisely, the sensitivity analysis showed that the higher the investment costs of the scenario, the lower the NPV and IRR values calculated, which actually means lower profits for the private investor. As it can be observed from the figures 41 and 42, the minimum scenario, where all types of PV parks are characterized by the lowest possible investment cost, shows the second highest NPV equal to 74.16 million € and the highest IRR equal to 6.97%. Contrariwise, the maximum scenario, where all types of PV parks have the highest possible investment cost, show the lowest NPV value equal to 22.89 million € as well as the lowest IRR value among all alternatives, equal to 4.13%. Comparing the low and the high investment cost curves with each other, it can be noted that the former parameter has a greater effect on the Project's profitability than the latter, since it has a bigger inclination. This can be easily explained, as the majority of the potential PV power parks (types "L-L" and "H-L") considered for the Project are located in in the country's mainland, where the capital costs are rather low. Consequently, as the capital-intensive "H-H" type PV parks located on the islands have less installed capacity and thus produce less energy in total, the fluctuation of the corresponding high investment costs has medium influence in the final calculations.

The second most important uncertain parameter of the Project was proved to be the capacity factor, which is reasonable since it determines the amount of energy produced and, consequently, the revenues. As expected, an increase in the capacity factor indicates an increase in the estimated NPV and IRR values and vice versa. It is worth mentioning that regarding this parameter, the minimum scenario examined, where all PV parks are located in the areas with the lowest solar potential possible, showed a very low NPV equal to 26.10 million € and a very low IRR equal to 4.38%. However, for the maximum scenario, with all PV parks utilizing the highest solar potential observed in the Greek territory, the NPV is equal to 70.95 million €, while the IRR is 6.43%, both among the highest values calculated for all plausible scenarios of the Project. Observing the low and the high capacity factor's curves as they emerged from the analysis, the latter has a greater effect on the NPV and IRR results compared to the former, as indicated by its steeper slope. The reason is similar to the one described in the case of the investment costs; the majority of the PV parks considered in the analysis are located in regions with high solar potential. As a result, even the slightest change in the high capacity factor values has a great influence on the produced energy, thus in the NPV and IRR calculated values.

Moving on to the effect of the share of loan on the Project's calculations, the influence observed is rather small. This is reasonable, since the share of loan is only related to the initial investment of the sub-projects and the repayment of the loan installments. However, the sensitivity analysis conducted on this uncertainty revealed a contradictory result. For the minimum scenario, which represented the lowest share of loan possible, the NPV is 49.24 million € and the IRR 5.17%. For the maximum scenario, where the share of loan took its highest value, the corresponding NPV and IRR values are 47.81 million € and 5.75% respectively. Those results demonstrate that as the share of loan increases the NPV value decreases, while the IRR value follows a reverse pattern than the NPV and increases. The behavior of the NPV factor can be explained easily, since the higher the share of the loan, the bigger the amount of money borrowed, thus the higher the loan-repayment amounts that have to be paid back over the years. Regarding the IRR's behavior, a higher loan indicates that a bigger part of the initial investment cost will be covered by the bank at the starting years of the Project, when its profitability is still limited. As a result, this gives a higher IRR value, even though the real profits of the private investor are actually lower compared to the scenario with the lower share of loan. As already mentioned before, such conflicting results between the NPV and IRR calculations can occur when comparing mutually exclusive scenarios and are due to the different initial investment and cash flow patterns between them.

As far as the real interest rate is concerned, we can conclude that it has a low significance in the NPV and IRR calculations, due to the limited range of possible values taken into account for the Project. The three aforementioned financial factors are characterized by a reverse relationship; thus an increase in the real interest rate causes a decrease in both of the NPV and IRR values. To be more precise, the minimum scenario examined, at which the real interest rate considered takes its lowest possible value, have a NPV equal to 52.49 million € and an IRR equal to 5.62%. At the maximum interest scenario, at which the real interest increases to its highest value, the corresponding NPV and IRR values calculated decrease to 44.56 million € and 5.22% respectively.

Lastly, the effect of the real discount rate should be discussed. Regarding the IRR calculations, it is observed that the IRR is equal to 5.42% for all plausible scenarios examined, by definition as explained earlier. However, the changes in the real discount rate have an evident influence in the

NPV calculations. Referring to the final form of the equation used to estimate the NPV for each scenario, it is expected that the higher the discount rate, the lower the NPV. This is confirmed by the results of the NPV calculations for the minimum and maximum scenarios of the Project. In the first case the NPV is taking its highest value equal to 77.46 million €, while in the second case its second lowest value equal to 24.63 million €.

6.3 Socio-Economic CBA

After completing the financial analysis, we move forward to the second and final part, the socio-economic analysis of the Project. In contrast to the financial, the socio-economic CBA introduces the concepts of social value and environmental sustainability into the calculations, in an effort to evaluate all costs and benefits that may affect society when the new project is implemented. As a result, in the following section the interest is shifted from the private investor's to the whole society's welfare.

In order to determine an accurate way of performing the SCBA calculations of the current Project, a large body of literature was reviewed, including detailed guidelines published and used by the European Commission for the evaluation of new investment projects. Our research showed that the European Commission utilizes the framework of SCBA to decide upon the co-financing of major projects included in operational programs (OPs) of the European Regional Development Fund (ERDF) and the Cohesion Fund. In our case, since the proposed Project is part of the European Renewable Energy Directive and there is no uniform SCBA methodology followed by the researchers among the literature assessed, the socio-economic calculations of this part will be performed according to the aforementioned EU's guidelines [145].

Based on the EU's SCBA approach, the following main steps should be realized in order to perform a complete SCBA of a project [188]:

- **Step 1:** Identification of the project, technical and demand analysis.
- **Step 2:** Financial analysis.
- **Step 3:** Correction for the fiscal effects.
- **Step 4:** Calculation of the positive and negative externalities.
- **Step 5:** From market prices to shadow prices.
- **Step 6:** Calculation of the economic return of the project.

From the above steps, it is clear that the methodology suggested by the EU's guides, consistent with international practice, attempts a transition from the financial to the economic analysis. To do so, shadow prices are implemented to reflect the social opportunity cost of goods and services, instead of prices observed in the market, which may be distorted. Moreover, positive and negative externalities are taken into consideration too, as they have a significant impact for the whole society's welfare and they should clearly be evaluated in the decision-making procedure of a project's proposal [145]. A brief explanation of each step is presented in the next section.

Step 1: Identification of the project, technical and demand analysis

The first step has to do with identifying the project which is about to be evaluated with the use of the SCBA method. In other words, it means defining all technical, financial and socio-economic aspects of the project. In our case, this step has already been performed at the beginning of the sub-chapter 6.1, where the study-plan of the current thesis was introduced and explained.

Step 2: Financial analysis

The second step is based on the financial CBA of the project. Conducted from the private investor's point of view, the financial CBA relies on the discounted cash-flow method to calculate the NPV and IRR of the project, as elaborated thoroughly in sub-chapter 6.2. However, major attention should be paid to the following point: While moving from the financial to the economic evaluation, costs such as depreciation, interest pay-offs and loan repayments need to be omitted. More precisely, depreciation should be excluded, because if included it would result in double-counting of the capital cost. Interest and loan repayments should be excluded too, as they don't affect the calculation of the interest rate that society can withstand from the implementation of a new project. In fact, both private investors and banks belong to "society" and have standing; thus the different ways of financing a project only indicate different ways of cash transfer between its members, not additional costs or benefits for them. Consequently, in order to perform the SCBA calculations for our project, the previous financial CBA calculations will be used, without considering depreciation expenses (D_t), loan (L_t), interest (I_t), and principal repayments (P_t) [189].

Step 3: Correction for the fiscal effects

At this step a further correction of the financial analysis should be performed in order to shift towards the socio-economic analysis. This correction relates to fiscal parameters such as taxes, levies, and subsidies, that do not constitute real economic costs or benefits for the groups of the society in standing but are mere money transfers between them. For example, a project's taxes are paid by consumers to the government, that in its turn redistributes them to consumers in the form of public expenditures. A similar cash recirculation but in reverse happens with the subsidies.

To avoid such distortions while conducting a SCBA, a set of several rules should be followed [145], [185]:

- Input and output prices should be considered net of VAT.
- Input prices should be taken into account net of direct and indirect taxes.
- Indirect taxes or subsidies intended as a correction for externalities (e.g. NO_x emission taxes, etc.) should be included, as long as they reflect the underlying marginal cost (WTP) sufficiently and are not double-counted.
- Prices (e.g. tariffs, etc.) used as a proxy for the value of outputs should be considered net of any subsidy and other transfer granted by any public entity.

Concerning our case-study and in order to align with the above mentioned rules, the annual income taxes (T_t) paid to the Greek government by the private investor will be deducted, as they are transfer payments within the Greek society. Regarding the rest of the points, it should be stated that all relevant financial data used in our CBA so far (e.g. costs of equipment, materials, etc.) are net of VAT, according to our relevant sources. Furthermore, no subsidies or other indirect taxes correcting for externalities have been applied. Lastly, the FIT scheme, based on which the price of the generated electricity is sold to consumers, is VAT inclusive. However, this will not interfere into our calculations, as the revenues of the project for the sake of the economic analysis will be estimated based on the consumers' willingness-to-pay for the produced solar energy instead of the FIT prices set by the government and used previously in the private investor's analysis.

Step 4: Calculation of the positive and negative externalities

At this point all externalities which were omitted in the financial analysis since they had no use to the private investor, should be included. In fact, these externalities constitute real costs and benefits for the society and play a crucial part in the socio-economic appraisal of a new project. The incorporation of these parameters in the SCBA calculations requires, firstly, their identification, secondly, their physical quantification and, lastly, their interpretation in monetary terms.

Although the theoretical background of all types of externalities relating to PV projects could be easily spotted in the relevant literature and is already elaborated previously, their practical implementation in SCBAs showed great inconsistency. Consequently, to eliminate possible confusions, our analysis will continue following the European Commission's methodology. Thus, the externalities considered in the calculations of our Project in Greece are summarized in table 24. The same externalities are presented and calculated in detail in the succeeding part of the sub-chapter [145].

Table 24: Positive & negative externalities of energy projects, as adopted by the European Commission [185].

Positive Externalities (External Benefits)	Negative Externalities (External Costs)
1. Avoided fuel costs by substitution of the energy source	**1. Additional measures for reducing potential environmental damages during construction & operation of the plant**
2. Increase of energy independence	**2. Other negative externalities (e.g. loss of land, visual & noise intrusion, etc.)**
3. Reduction of GHG and air pollutant emissions	

Positive Externalities

Before proceeding to the actual reckoning of the positive externalities, it should be reminded that our Project studies the transition from conventional to PV solar power for electricity production. According to the latest updates, during 2013 electricity in Greece was generated 46% by lignite, 19% by natural gas, 9.5% by oil, 25% by RES and 0.5% by other non-RES sources such waste [149]. Based on the aforementioned electricity mix, the energy produced by the proposed PV plants of the current project is supposed to substitute all conventional fuel sources, so lignite, natural gas and oil. The total contribution of these sources to the Greek energy generation field is 74.5%.

In order to monetize and include these benefits in the socio-economic calculations of our Project, firstly we need to identify the kind and quantity of fossil fuels that will be substituted by the PV power plants of the Project. As mentioned earlier, the Greek electricity generation mix in 2013 was 46% lignite, 19% natural gas, 9.5% oil, 25% RES and 0.5% other non-RES sources. Among the possible type of PV plants considered in our analysis, the “L-L” and “H-L” types are intended to be installed in the mainland of Greece, while the “H-H” in the non-interconnected islands. Regarding the primary conventional energy sources in the Greek territory, lignite and natural gas are prevailing in the electricity production of the mainland, while oil is the exclusive fossil fuel used for electricity generation in the islands.

According to the above information and assuming that the proposed PV parks will displace electricity produced by lignite, natural gas and oil fired plants proportionally to their current usage, the relevant socio-economic calculations of this part are performed on the following basis:

- “L-L” & “H-L” types of PV parks substitute 70.77% of lignite and 29.23% of natural gas.
  In other words, 1 KWh of “L-L” & “H-L” PV plants displaces 0.7077 KWh of electricity produced by lignite and 0.2923 KWh of electricity produced by natural gas.
- “H-H” type of PV parks substitute 100% of oil.
  This means that 1 KWh of “H-H” PV plants displaces 1 KWh of electricity produced by burning fuel oil.

- ***Avoided fuel costs by substitution of the energy source – External Benefit I***

The implementation of PV technology can lead to a gradual reduction in the use of conventional energy resources. This imposes a positive outcome for a country’s economy considering the fuel costs of the thermal power stations that can be avoided, as these sources can be either saved for the future or used for alternative purposes. Since lignite is virtually the only indigenous fossil fuel available in Greece, this external benefit relates to the avoided costs of lignite extraction and consumption.

In our analysis, it is assumed that the “L-L” and “H-L” types of PV power plants proposed will be located on the mainland, thus they will be the ones displacing the lignite fired power plants currently in operation. As demonstrated before, 1 KWh of energy produced by these two categories substitutes 0.7077 KWh of electricity produced by conventional lignite plants, which is a quite significant amount of fuel saved. In order to estimate these fuel savings, the relevant equation that is used, has been introduced in the previous chapters and is the following:

$$M_{lignite} = E_{lignite} / \eta_d \cdot H_u$$

where:

- $M_{lignite}$: the annual amount of lignite produced
- $E_{lignite}$: the amount of lignite energy that will be replaced with the PV energy produced by “L-L” and “H-L” PV parks, which can be calculated as follows:

$$E_{lignite} = 0.7077 \cdot E_{"L-L"\&"H-L"types} \xrightarrow{E_{"L-L"\&"H-L"types}=1kWh} E_{lignite} = 0.7077kWh$$

- η_d : the efficiency of a typical lignite fired power plant, which is currently described by an average 32–33%, so for our calculation the mean value will be considered [190]:

$$\eta_d = 32.5\%$$

- H_u : the corresponding specific calorific value of the lignite consumed. According to current data, Greek lignite is of low quality overall and its calorific value ranges from 975 to 2257 kcal/kg, depending on the region of extraction. For our calculation, the mean calorific value will be used, thus [191]:

$$H_u = 1616 kcal / kg_{lignite} \xrightarrow{1kcal = 0.001163\text{kWh}} H_u = 1.879408 kWh / kg_{lignite}$$

Hence:

$$M_{lignite} = \frac{0.7077}{0.325 \cdot 1.879408} \cdot \frac{kWh}{kWh / kg_{lignite}} = 1.1586 kg_{lignite}$$

Knowing the annual amount of lignite that will be replaced by the operation of the proposed "L-L" and "H-L" PV power plants, we can estimate the occurring avoided fuel costs, based on the production costs of the lignite in Greece. According to a study conducted for Greece in 2012 by Booz&Co, the cost of lignite extraction is one of the lowest among other European countries and is equal to 2.12 €/ton. Taking into account the extremely low calorific value of Greek lignite as well as other variable production cost parameters, the final production cost of lignite-fired power generation in Greece was equal to 14.82 €/ton in 2012 [191], [192]. Since our Project is realized in 2016, the aforementioned value should be recalculated in order to include the effect of inflation during the years. As explained previously, this can be achieved with the use of the Consumer's Price Index indicator between the years 2012 and 2016. Based on the information given in table 21 and the corresponding literature [181], we have:

$$CPI_{2016} / CPI_{2012} = 104.150 / 111.34 = 0.9354$$

Therefore, the production cost of lignite for the year 2016 is equal to:

$$\Pr oductionCost_{lignite} = 0.9354 \cdot 14.82 = 13.863 \text{€/ton}$$

Consequently, the first external benefit for every KWh of the "L-L" and "H-L" PV power plants can be estimated by the following equation:

$$External\_Benefit\_(I) = M_{lignite} \cdot \Pr oductionCost_{lignite} = 1.1586 \cdot 10^{-3} \cdot 13.863 = 0.0161$$

€/kWh

- ***Increase of energy independence– External Benefit II***

One more external benefit that occurs from the implementation of renewable energy projects in general and of our PV Project in particular is that such projects encourage a country to rely on itself in terms of energy supply, thus reducing its dependence on fossil fuel imports from others. The importance of this benefit is dual; firstly, it can be directly translated as money savings for the country and secondly, it contributes partially to the security of energy supply, since the country doesn't depend on others, something that increases its stability especially in times of economic or other national crises.

In our case, Greece imports all fuels necessary for the operation of its natural gas and oil-fired power plants. As already mentioned, we assume that 1 kWh of energy produced by the "L-L" and "H-L" types of PV power plants of the Project substitutes 0.2923 kWh of energy produced by natural gas power plants in the Greek mainland. Respectively, 1 kWh of the energy produced by the "H-H" type of PV parks located on the Greek islands replaces 1 kWh of electricity produced by oil-fired installations. Similar to the case of lignite, the procedure followed for the estimation of the avoided costs of fuel imports of both natural gas and oil is presented below:

Natural Gas – External Benefit IIa

$$M_{NG} = E_{NG} / \eta_d \cdot H_u$$

where:

- M_{NG} : the annual amount of natural gas imported
- E_{NG} : the amount of natural gas produced energy that will be replaced with the PV energy produced by "L-L" and "H-L" PV parks, equal to:

$$E_{NG} = 0.2923 \cdot E_{"L-L"\&"H-L"types} \xrightarrow{E_{"L-L"\&"H-L"types}=1kWh} E_{NG} = 0.2923kWh$$

- η_d : the efficiency of a typical natural gas power plant, which is considered [167]:

$$\eta_d = 40\%$$

- H_u : the corresponding specific calorific value of the natural gas consumed, equal to [167]:

$$H_u = 47MJ / kg_{NG} \xrightarrow{1MJ=0.277778kWh} H_u = 13.056kWh / kg_{NG}$$

Hence:

$$M_{NG} = \frac{0.2923}{0.40 \cdot 13.056} \cdot \frac{kWh}{kWh / kg_{NG}} = 0.056kg_{NG}$$

After defining the amount of imported natural gas that will be avoided, the cost of import of this fuel should be determined in order to calculate the corresponding external benefit. According to the European Commission's Guidelines, the border price rule is generally used to estimate shadow prices of internationally marketable goods entering as inputs in a project. This method estimates the trade opportunity cost of goods, assuming that international prices reflect the economic value of imported goods better than domestic ones, as the latter can be easily affected by the national market's distortions. Following the border price rule, the shadow price of a tradable good is given by its CIF (cost, insurance and freight) price at the national border, thus including the cost of production, insurance and freight borne to bring the good as far as the national border, but excluding any custom duties, taxes or subsidies applied once the good enters the national market [145].

For the case of Greece, the Regulatory Authority for Energy provides the relevant information about the CIF price of natural gas imports for periods of three years. The latest data that could be retrieved relate to the period from January 2013 to December 2015 and, as shown in figure 45, big fluctuations can be observed in the weighted average import prices of natural gas, ranging from 33.3 to 19 €/MWh [193]:

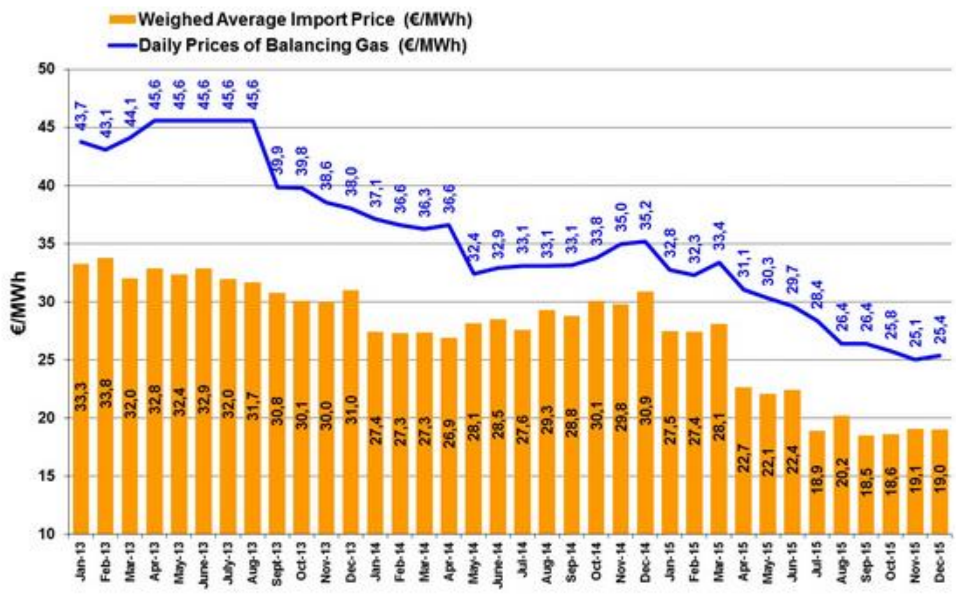


Figure 45: Monthly data on WAIP of Natural Gas for the period of January 2013 – December 2015 [193].

For our calculations, the most recent available data of December 2015 will be used, which is equal to 19 €/MWh for natural gas imports in Greece. Consequently, external benefit IIa can be estimated by the following formula:

$$External\_Benefit\_(IIa) = M_{NG} \cdot H_u \cdot price_{NG} = 0.056 \cdot 13.056 \cdot 19 \cdot 10^{-3} = 0.0139 \text{€/kWh}$$

Crude Oil - External Benefit IIb

The exact same procedure is followed for the calculation of the avoided fuel import costs for the case of crude oil. Therefore:

$$M_{Oil} = {E_{Oil}}/{\eta_d \cdot H_u}$$

where:

- M_{Oil} : the annual amount of crude oil imported
- E_{Oil} : the amount of crude oil-produced energy that will be replaced with the PV energy produced by "H-H" PV parks, equal to:

$$E_{Oil} = E_{"H-H" types} = 1kWh$$

- η_d : the efficiency of a typical oil-fired power plant, which is considered [167]:

$$\eta_d = 34\%$$

- H_u : the corresponding specific calorific value of the oil consumed, equal to [167]:

$$H_u = 40MJ/kg_{Oil} \xrightarrow{1MJ=0.277778kWh} H_u = 11.11kWh/kg_{Oil}$$

Hence:

$$M_{Oil} = \frac{1}{0.34 \cdot 11.11} \cdot \frac{kWh}{kWh/kg_{Oil}} = 0.265kg_{Oil}$$

Subsequently, the CIF price of crude oil imported in Greece is necessary for the estimation of the external benefit deriving from the avoided import costs of the corresponding fuel. Such information is available for all members of the European Union on a yearly basis by the European Commission. The most recent data for all EU member states, as well as for Greece, dated on the 1st of December 2015, are presented in table 25 [194]:

Table 25: Average CIF costs for the supply of crude oil among EU-members, dated 1st December 2015 [194].

	Approvisionnement total Total supply Import + Inlandsförderung		Coût caf moyen / Average cif cost / Gewichteter mittlerer cif-Preis ($)		Coût caf moyen / Average cif cost / Gewichteter mittlerer cif-Preis (€)	
	1000 barils 1000 barrels 1000 Barrel	1000 tonnes 1000 Tonnen	par baril per barrel pro Barrel	par tonne per tonne pro Tonne	par baril per barrel pro Barrel	par tonne per tonne pro Tonne
Austria	61865.57	8109.00	55.56	423.83	49.92	380.87
Belgium	232786.13	31534.22	51.61	381.13	46.37	342.49
Bulgaria	43440.70	6021.40	50.61	365.31	45.48	328.28
Croatia	15643.00	2151.00	55.22	400.62	49.79	361.21
Denmark	53379.00	7128.85	52.73	394.83	47.38	354.80
Finland	348390.33	47980.01	51.41	346.80	46.20	311.65
France	433719.20	57700.17	53.49	402.09	48.07	361.33
Germany	637884.00	85945.00	52.57	390.09	47.24	350.55
Greece	161669.00	22095.00	50.38	369.04	45.27	331.63
Hungary	49549.45	6815.55	*(3)*	*(3)*	*(3)*	*(3)*
Ireland	24476.72	3269.68	53.38	400.14	47.96	359.57
Italy	450184.05	62483.07	52.24	377.95	46.94	339.63
Lithuania	61386.60	8479.52	50.66	366.80	45.52	329.62
Netherlands	441916.00	59829.13	51.78	382.65	46.53	343.86
Poland	191392.84	26491.72	49.92	360.70	44.86	324.13
Portugal	101969.89	13833.43	53.46	394.24	48.04	354.27
Romania	74056.79	10167.82	49.79	362.74	44.75	325.97
Slovakia	42978.59	5970.27	50.49	363.50	45.38	326.65
Spain	465491.62	64627.57	49.50	356.50	44.48	320.36
Sweden	145828.00	19938.00	51.89	379.54	46.63	341.07
United Kingdom	377441.86	50346.69	53.08	397.95	47.70	357.61
EU 28	**4415449.33**	**600917.09**				
CE/EC/EG EUR 28 (4) Moyenne pondérée Weighted average Gewichteter Durchschnitt			**51.85**	**379.13**	**46.60**	**340.7**
CE/EC/EG Euro Area 19 (5) Moyenne pondérée Weighted average Gewichteter Durchschnitt			**51.87**	**378.44**	**46.61**	**340.07**

Consequently, external benefit IIb is calculated as follows:

$$External\_Benefit\_(IIb) = M_{Oil} \cdot price_{Oil} = 0.265 \cdot 10^{-3} \cdot 331.63 = 0.0879 \text{€/kWh}$$

Having established the values of the external benefits resulting from the natural gas and crude oil avoided imports, it should be mentioned that the volatility of the import prices of both fuels observed over the years has a great impact in our socio-economic calculations. Therefore, a sensitivity analysis is performed, where except for the baseline scenario, two more scenarios are examined, considering higher and lower import prices for both of the fuels.

Since natural gas is often a byproduct of drilling for crude oil, there is, undoubtedly, a correlation between the prices of those two fuels. In addition, as crude oil and natural gas substitute one another, the competition between them creates a rule of dependence, which is sometimes positive but can also have times of disengagement. However, determining the exact relationship between these fuels is difficult, since it changes over time and it is not the same for every country. For the case of Greece, a study was conducted considering the two fuels' historical CIF prices from January 2004 to September 2012. According to the study's findings, the import price of crude oil affects the import price of natural gas and not vice versa, and the relation between them is the following [195]:

$$price_{NG} = 0.555956 \cdot price_{Oil}$$

As mentioned earlier, for the purpose of our sensitivity analysis, we consider a minimum and a maximum scenario where the import price of crude oil is decreased and increase by 40% accordingly compared to the price of the baseline approach, thus the calculations of the external benefits deriving from the avoided imports are formulated as shown below per scenario:

Minimum Scenario

- $price_{Oil}^{\min} = 0.6 \cdot 331.63 = 199$ €/ton
- $price_{NG}^{\min} = 0.555956 \cdot 199 = 110.64$ €/ton
- $External\_Benefit\_(IIa)^{\min} = M_{NG} \cdot price_{NG}^{\min} = 0.056 \cdot 10^{-3} \cdot 110.64 = 0.0062$ €/kWh
- $External\_Benefit\_(IIb)^{\min} = M_{Oil} \cdot price_{Oil}^{\min} = 0.265 \cdot 10^{-3} \cdot 199 = 0.053$ €/kWh

Maximum Scenario

- $price_{Oil}^{\max} = 1.4 \cdot 331.63 = 464.3$ €/ton
- $price_{NG}^{\max} = 0.555956 \cdot 464.3 = 258.13$ €/ton
- $External\_Benefit\_(IIa)^{\max} = M_{NG} \cdot price_{NG}^{\max} = 0.056 \cdot 10^{-3} \cdot 258.13 = 0.0145$ €/kWh
- $External\_Benefit\_(IIb)^{\max} = M_{Oil} \cdot price_{Oil}^{\max} = 0.265 \cdot 10^{-3} \cdot 464.3 = 0.123$ €/kWh

- ***Reduction of GHG and air pollutant emissions – External Benefit III***

Last but not least, the replacement of conventional energy sources with the proposed PV power plants of our Project creates benefits associated with the reduction of GHG and other air pollutant emissions. The great advantage of such a reduction is obvious for both parameters; GHG have a considerably negative impact on the global climate, while the rest of the pollutants in the form of gases, liquids and solids influence unfavorably the environment and human health. A detailed analysis of these externalities and their effects preceded in chapter 5, so at this point the estimated values of the ExternE and CASES projects will be used as plug-in values in order to proceed with the calculations.

To be more specific, the calculation of the external benefit III for all types of PV power plants considered in the Project, is based on the values of external costs of conventional power generation estimated by the CASES project, as can be retrieved by table 13. Due to the fact that these values were estimated in 2006, they should be recalculated, taking into consideration the inflation over the years. The factor used for this conversion is based on the Consumer's Price Index of the years 2006 and 2016 and is the following [181]:

$$CPI_{2016} / CPI_{2006} = 104.150 / 92.196 = 1.1297$$

Consequently, for 2016 the external costs of each conventional energy source used in Greece are:

- $Lignite \Rightarrow 32.92 \cdot 1.1297 = 37.19$ €/MWh
- $NaturalGas \Rightarrow 8.23 \cdot 1.1297 = 9.297$€/MWh
- $Oil \Rightarrow 22.61 \cdot 1.1297 = 25.543$€/MWh

Taking into account the external costs calculated above as well as the proportions of the fossil fuels that will be displaced by the PV technology, the external benefit III for each type of PV power park in terms of energy produced, will be the following:

$$External\_Benefit\_(IIIa)_{"''L-L"\&"H-L"types} = (0.7077 \times 37.19) + (0.2923 \times 9.297) \Rightarrow$$

$$External\_Benefit\_(IIIa)_{"''L-L"\&"H-L"types} = 29.037 \text{ €/MWh}_{solar}$$

And:

$$External\_Benefit\_(IIIb)_{"H-H"types} = 1 \times 25.543 = 25.543 \text{ €/MWh}_{solar}$$

Negative Externalities

After defining the external benefits of the Project, we are moving on to determine the external costs that need to be taken into account in our SCBA calculations, as pointed out by the European Commission's method. More precisely, these negative externalities are:

- The additional measures for reducing potential environmental damages occurring during construction and operation of the power plants and
- Other negative externalities such as loss of land, spoiling of scenery, biodiversity, etc.

As all of the aforementioned parameters are already examined and included in the results of the CASES project, discussed thoroughly in chapter 5, the negative externalities of our Project will be calculated by using the corresponding plug-in value for photovoltaics in open area for the country of Greece. According to table 14, the external costs of PV energy for the period 2005-2010, including all damages caused to human health and environment, are equal to 6.369 €/MWh. Once again, this value should be updated for 2016, which is the year of the first PV installation, based on the corresponding Consumer's Price Indexes of the years 2006 and 2016:

$$CPI_{2016} / CPI_{2006} = 104.150 / 92.196 = 1.1297$$

Thus:

$$External\_Costs = 1.1297 \cdot 6.369 \cdot 10^{-3} = 0.007195 \text{€/kWh}$$

The above figure is common for all types of PV power plants proposed and it will be used for the calculation of the external costs imposed to the Greek society by our Project.

Step 5: From market prices to shadow prices

In the context of a socio-economic analysis, market prices are no longer relevant to assess a project's contribution to the welfare of society. Consequently, the purpose of step 5 is to convert all costs and benefits considered at the financial analysis and valued at the corresponding market prices, to the so-called 'shadow prices'. This term refers to the opportunity cost to the society of producing or consuming more or less of any good. In perfectly competitive and efficient markets, market and shadow prices are the same. In reality, however, they usually differ mainly due to the reasons below [145], [185]:

- Real prices of inputs and outputs are distorted because of inefficient markets (distortions of markets may be caused by taxes, duties, subsidies, rigid exchange rates, rations on production or consumption, regulated tariffs, oligopoly or monopoly price setting and imperfect information)
- Governments set non cost-reflective tariffs of public services

- Market wages do not represent the real opportunity cost of labour.

As already stated, in cases as the above, the usual approach is to convert market into shadow prices which will then be implemented into the former financial analysis. There are several ways to calculate the shadow price of a good, depending on whether it constitutes an input or an output of the project. According to the European Commission's methodology for the assessment of projects, the following guideline is applied:

- **Project Inputs**

For internationally tradable goods, border prices should be used. Border prices are in fact international prices, CIF (Cost, Insurance & Freights) for imports (e.g. natural gas and crude oil) and FOB (Free on Board) for exports, expressed in the same currency. Where the relevant economic border lies is decided on a case-by-case basis. In the context of the EU funds, the external border of the EU may be considered sufficient for most goods [145], [185].

As far as non-tradable goods are concerned, different approaches can be used whether we refer to major or minor items. More precisely, for major items (e.g. land, civil works, machinery, equipment, etc.) and depending on the size of their effect on social welfare, the estimation of shadow prices can be done either by defining their long term marginal cost or by considering the willingness-to-pay method. Great care should be taken regarding the LTMC method, which can be applied only when the cost structure is known or can be easily identified. Otherwise the standard conversion factor approach, described next, could be applied as an alternative. For minor items (e.g. administrative costs, intermediate services, etc.) the standard conversion factor (SCF) method is applied. The latter term indicates the average distance between world and domestic prices, under the assumption that the former reflects the opportunity cost of the good and that the latter is distorted compared to international prices. The lower the distortion of the domestic market, the closer the SCF is to unity. The general equation for the estimation of the SCF is the following [145], [185]:

$$SCF = \frac{M + X}{(M + T_M - S_M) + (X - T_X + S_X)}$$

where:

- M : the total CIF value of imports
- X : the total FOB value of exports
- T_M , T_X : the value of duties on import and export respectively
- S_M , S_X : the value of subsidies on import and export respectively.

Taking into account that [145]:

- ✓ Import subsidies are no longer provided by EU institutions or national governments

  → $S_M = 0$

- ✓ Export subsidies throughout the EU are expected to be completely eliminated soon, in compliance with the WTO (World Trade Organization) agreement

  → $S_X = 0$

- ✓ Exports to other EU Member States and third countries are free of taxes

  → $T_X = 0$

the formula for the estimation of the SCF is simplified into:

$$SCF = \frac{M + X}{M + X + T_M}$$

For our calculations, the SCF should be used by default when specific sectoral conversion factors are unavailable. Moreover, it should be equal to one, in cases where its calculation is impossible [145], [185].

- **Project Outputs**

The willingness-to-pay approach (WTP), measuring the maximum amount consumers are willing to pay for a unit of a given good, is suitable for estimating the direct benefits of a proposed project. In practice, the economic analysis evaluation of the project's direct benefits takes place by substituting the financial revenues, in the form of users' fees, charges or tariffs, with the estimation of the users' WTP for project outputs less changes in supply costs. In cases where the WTP approach is not possible, the long-run marginal cost (LRMC) method can be used instead. Based on empirical observations, WTP is usually higher than LRMC [145], [185].

- **Labour Cost**

As an input to the project, labour can be regarded as a social cost and a social benefit at the same time. To explain this statement better, additional employment is a social cost, since it represents the labour resources occupied by a project that can no longer be used for alternative social purposes. However, it is also a benefit, considering the extra income generated in favor of the society due to job creation. Structural characteristics of local labour markets, such as the existence of a legal minimum wage, taxes, social contributions, subsidies, and unions, cause the opportunity cost of labour to differ from its market wage, which, depending on the case, may be overestimated or underestimated. However, employment cannot be treated either as a tradable or as a non-tradable good; hence an alternative approach should be followed in order to convert market to shadow prices, called the shadow wage (SW) approach. More precisely, shadow wage reflects the labour's social opportunity cost rather than its unrepresentative market value. The shadow wage approach is based on special coefficients, named conversion factors (CF), which are used for the conversion of the observed market wages to the corrected shadow ones that should be included in the socio-economic analysis of the project [145], [196].

After defining the alternative approaches for the estimation of the shadow prices of goods, we move on to present their implementation in the actual SCBA calculations of a project. In practice, the transformation of the inputs' market prices into shadow prices is achieved with the use of Conversion Factors (CF). By definition, these CFs are the ratio between shadow and market prices and represent the factor at which market prices have to be multiplied to obtain inflows valued at shadow price. Conversion Factors can take values higher than one, indicating that the opportunity cost of a good is higher than that captured by the market, or lower than one, meaning that the observed price is higher than the shadow price, due to market distortions. In principle, CFs should be uniform and not calculated on a project-by-project basis. In the absence of evidence of market failures, the CFs should be set equal to unity [145], [185].

Regarding our Project, after completing steps 1, 2, 3 and 4 of the European Commission's methodology, the social costs and benefits that are taken into account in the socio-economic analysis are formed as shown in table 26 below:

Table 26: Annual Social Costs & Benefits considered in the SCBA calculations of the Project.

Annual Social Benefits	Annual Social Costs
Revenues	**Investment Costs**
External Benefit I	**O&M Costs**
External Benefit IIa & IIb	**External Costs**
External Benefit IIIa & IIIb	
Salvage Value	

After identifying the social benefits and costs relevant to our Project, appropriate conversion factors should be granted to each of them in order to estimate their shadow prices. According to the methodology, parameters with greater complexity should be split into their main components, since each of them should be assigned with a proper shadow price. In our case, these parameters are the investment and the O&M costs.

Investment costs consist of the following components:

- Preliminary studies, comprising 100% by labour costs, which correspond to the money spent for the planning, documenting and general engineering of the Project
- Imported solar PV equipment, including PV modules, inverters, transformers, switchgears, etc.
- Civil works, that can be translated partly as labour costs (mounting and installation of PV systems) and partly as domestic equipment (infrastructure).
- Electrical works, divided into labour costs (grid connection) and both imported and domestic equipment (e.g. DC cabling, transformers, switchgears, etc. for grid reinforcement and expansion).

Regarding O&M costs, we can distinguish the components below:

- Owner's costs, such as land rent, property taxes and insurance
- Labour costs, occurring during operation and maintenance of the power plants
- Imported and domestic equipment, considering potential replacements of equipment.

Apparently, the share of each cost in the estimation of the total investment and O&M expenditure depends greatly on the type of the PV power plant. For example, the "H-H" type plants are characterized by higher civil and electrical works, as a result of their unfavorable location. A summary of all of the aforementioned information regarding the proper conversion factors that will be included in our socio-economic analysis, can be found in the next table 27:

Table 27: Estimation of the Conversion Factors (CFs) appropriate for every cost and benefit. Based on data found on [145].

Cost / Benefit	Conversion Factor (CF)
Preliminary Studies	CF of labour market
Imported Equipment	(1 – Import duty) * (1-VAT)
Domestic Equipment	SCF
Civil Works	Weighted Average of the components' CFs
Electrical Works	Weighted Average of the components' CFs
Owner's Costs	SCF (as a minor non-tradable good)
Labour Costs	CF of labour market
Investment Costs	Weighted Average of the components' CFs
O&M Costs	Weighted Average of the components' CFs
External Costs/Benefits	SCF (as non-tradable goods)
Revenues	CF method irrelevant, WTP approach followed
Salvage Value	CF of investment costs

Proceeding with the analysis, the next step is to assign appropriate values to the CFs mentioned above. According to the European Commission's methodology, the issuance of conversion factors for every sector is an individual responsibility of each Member State and, once published, CFs should be used consistently for the evaluation of potential projects and policies on a national level. Unfortunately, such CFs are not available for the case of Greece. Similar difficulties arise in the calculation of the standard conversion factors as well. More specifically, information on the CIF value of total imports (M) and the FOB value of total exports (X) can be found in databases published by Eurostat with reference to all EU members. However, the taxes on imports (T_M) and exports (T_X) relevant to the inputs of our Project are considered as confidential data and are not applicable for the purposes of this study. Due to this limitation, for the costs and benefits that need to be converted to shadow prices with the use of a sector specific CF or the SCF approach, we assume SCF to be equal to unity. Thus for preliminary studies, domestic equipment, owner's costs and external costs/benefits CF=1.

Regarding the imported equipment, all parts required for the realization of the PV power plants, including those useful for the civil and electrical works, are considered to be imported from other EU member states. Since imports and exports within the EU are generally free of taxes and the costs of the inputs we considered for the Project are excluding VAT, for imported equipment the CF is equal to one [145].

Further with our analysis, the CF of labour costs should be determined. For this reason, European Commission uses the results of an empirical methodology, which was conducted in order to estimate the shadow wages prevailing in the EU for the year 2007. This methodology distinguishes four labour market conditions at regional level, which differ in terms of per-capita GDP, short- and long-term unemployment, migratory movements and the role of agriculture in the regional economy. For each of the aforementioned conditions an empirical formula for the calculation of the shadow wage is proposed, deriving from a common theoretical framework. For the case of Greece, three different labour market conditions were identified, characterized by the corresponding CFs [145], [185]:

- ***<u>"Quasi-Keynesian" unemployment</u>***
  Mostly encountered in the north regions of the country, with CF=0.54
- ***<u>"Urban labour dualism"</u>***
  Mainly observed in the Greek islands, with CF=0.80
- ***<u>"Rural labour dualism"</u>***
  Evident in the middle and south of Greece, with CF=0.62

Taking into account all of the three market conditions present in Greece, the CF of labour considered in our analysis will be their mean average:

$$CF_{labour} = \frac{(0.54 + 0.80 + 0.62)}{3} = 0.65$$

Due to the fact that estimating the real cost of labour depends on multiple parameters and gets highly influenced by market distortions, it is considered as an uncertain input to the Project. This means that a sensitivity analysis relevant to this parameter should be performed. Similar to the financial analysis, except for the baseline scenario, where CF=0.65, two more scenarios will be checked where the minimum and maximum possible values of the CF of labour market will be considered. Considering the range of the CF values evident in the Greek territories, it is safe to assume that the minimum and maximum CFs are equal to 0.45 and 0.85 respectively.

Having assigned values to all of the basic conversion factors, we move on to the computation of the more complex ones, which are relevant to the investment and O&M costs. These CFs will be used to convert the investment & O&M costs calculated in the financial part, from market to shadow prices, as necessary for the socio-economic evaluation of the Project. Based on the breakdown CAPEX and OPEX costs of regular PV systems, presented already in figure 33, and the opinion of experts in the field of solar energy in Greece, we can perform the following calculations [127]:

- ***<u>CF of the investment cost of "L-L" type PV power plants</u>***

  Assuming that the investment cost of an "L-L" type of PV power plant consists of 1.5% preliminary studies, 80% imported equipment, 9.5% civil works (76% labour costs - 24% domestic equipment) and 9% electrical works (37.5% labour costs - 32.15% domestic - 31.25% imported equipment), we have [127]:

  $$\left.\begin{aligned} CF_{labour} &= 0.65 \\ CF_{Imported\_Equipment} &= 1 \\ CF_{Domestic\_Equipment} &= 1 \end{aligned}\right\} \Rightarrow$$

  $$CF^{"L-L"}_{Investment\_cost} = 0.015 \cdot 0.65 + 0.8 \cdot 1 + 0.095 \cdot (0.76 \cdot 0.65 + 0.24 \cdot 1) + 0.09 \cdot (0.375 \cdot 0.65 + 0.3125 \cdot 1 + 0.3125 \cdot 1) = 0.958$$

- ***<u>CF of the investment cost of "H-L" type PV power plants</u>***

  For the "H-L" type of PV power plants the investment costs derive from of 1.5% preliminary studies, 66% imported equipment, 16.5% civil works (76% labour costs - 24% domestic equipment) and 16% electrical works (37.5% labour costs - 32.15% domestic - 31.25% imported equipment), thus similarly we calculate [127]:

  $$CF^{"H-L"}_{Investment\_cost} = 0.015 \cdot 0.65 + 0.66 \cdot 1 + 0.165 \cdot (0.76 \cdot 0.65 + 0.24 \cdot 1) + 0.16 \cdot (0.375 \cdot 0.65 + 0.3125 \cdot 1 + 0.3125 \cdot 1) = 0.93$$

- ***CF of the investment cost of "H-H" type PV power plants***

  Following the same procedure, the investment costs of the "H-H" type of PV power plants consist of 1.5% preliminary studies, 55% imported equipment, 22% civil works (76% labour costs - 24% domestic equipment) and 21.5% electrical works (37.5% labour costs - 32.15% domestic - 31.25% imported equipment), the conversion factor will be equal to [127]:

  $$CF^{"H-H"}_{Investment\_\cos t} = 0.015\cdot 0.65 + 0.55\cdot 1 + 0.22\cdot(0.76\cdot 0.65 + 0.24\cdot 1) +$$
  $$0.215\cdot(0.375\cdot 0.65 + 0.3125\cdot 1 + 0.3125\cdot 1) = 0.908$$

- ***CF of the O&M cost***

  The conversion factor for the O&M costs is uniform for all types of PV plants taking part into the Project. These costs comprise of 1.5% labour costs, 32% owner's cost, and 66.5% imported and domestic equipment [197], thus the estimated CF value is:

  $$CF_{O\&M\_\cos t} = 0.015\cdot 0.65 + 0.32\cdot 1 + 0.665\cdot 1 = 0.995$$

Since the CF of labour will be checked through a sensitivity analysis for a minimum and a maximum value scenario, the corresponding investment and O&M costs should be estimated accordingly. The relevant calculations can be seen below:

- $$CF^{\min}_{Investment\_\cos t\_"L-L"} = 0.015\cdot 0.45 + 0.8\cdot 1 + 0.095\cdot(0.76\cdot 0.45 + 0.24\cdot 1) +$$
  $$0.09\cdot(0.375\cdot 0.45 + 0.3125\cdot 1 + 0.3125\cdot 1) = 0.933$$
- $$CF^{\max}_{Investment\_\cos t\_"L-L"} = 0.015\cdot 0.85 + 0.8\cdot 1 + 0.095\cdot(0.76\cdot 0.85 + 0.24\cdot 1) +$$
  $$0.09\cdot(0.375\cdot 0.85 + 0.3125\cdot 1 + 0.3125\cdot 1) = 0.982$$
- $$CF^{\min}_{Investment\_\cos t\_"H-L"} = 0.015\cdot 0.45 + 0.66\cdot 1 + 0.165\cdot(0.76\cdot 0.45 + 0.24\cdot 1) +$$
  $$0.16\cdot(0.375\cdot 0.45 + 0.3125\cdot 1 + 0.3125\cdot 1) = 0.89$$
- $$CF^{\max}_{Investment\_\cos t\_"H-L"} = 0.015\cdot 0.85 + 0.66\cdot 1 + 0.165\cdot(0.76\cdot 0.85 + 0.24\cdot 1) +$$
  $$0.16\cdot(0.375\cdot 0.85 + 0.3125\cdot 1 + 0.3125\cdot 1) = 0.97$$
- $$CF^{\min}_{Investment\_\cos t\_"H-H"} = 0.015\cdot 0.45 + 0.55\cdot 1 + 0.22\cdot(0.76\cdot 0.45 + 0.24\cdot 1) +$$
  $$0.215\cdot(0.375\cdot 0.45 + 0.3125\cdot 1 + 0.3125\cdot 1) = 0.855$$
- $$CF^{\max}_{Investment\_\cos t\_"H-H"} = 0.015\cdot 0.85 + 0.55\cdot 1 + 0.22\cdot(0.76\cdot 0.85 + 0.24\cdot 1) +$$
  $$0.215\cdot(0.375\cdot 0.85 + 0.3125\cdot 1 + 0.3125\cdot 1) = 0.961$$

- $CF_{O\&M\_\cos t}^{\min} = 0.015 \cdot 0.45 + 0.32 \cdot 1 + 0.665 \cdot 1 = 0.992$
- $CF_{O\&M\_\cos t}^{\max} = 0.015 \cdot 0.85 + 0.32 \cdot 1 + 0.665 \cdot 1 = 0.998$

Continuing the socio-economic analysis, the next step is to estimate the annual revenues of the Project. As mentioned previously, this specific calculation is not based on the conversion factor's but instead on the consumers' willingness to pay (WTP) approach. In other words, in contrast to the financial analysis where revenues result from multiplying the energy produced with the corresponding feed-in tariff, here the revenues derive from the multiplication of the aforementioned energy with the Greek consumers' willingness to pay for electricity generated by photovoltaics. With regards to the public attitude towards solar PV energy, a research conducted all over Greece in the period December 2011 – February 2012 showed that Greek citizens are adequately informed and sufficiently willing to invest in PV systems, either on their residence or on a plot of land. Greeks receive the necessary information mainly from the internet, their family and friends, while their final decision to invest or not is affected not only by their family but also by their financial status. According to the same study, the emerging factors that influence Greek people in proceeding or not with the installation of a PV system are mostly related to national interest and environmental protection reasons. Despite identifying easily the positive public attitude towards solar energy in Greece, assigning the proper value for the people's willingness to pay for it is a very difficult task, since, to our knowledge, there is no literature available on this matter. As a result, for the purpose of the current analysis, we will rely on the calculated WTP values of renewable energy in general, as stated in a research conducted for a specific region of Greece [198].

More precisely, the study was conducted in 2009, aiming to assess the citizens' public acceptance and willingness to pay for Renewable Energy Sources in Crete. For this purpose, residents of 1440 households all over Crete were interviewed face-to-face. The results of the study showed with a certainty of 95% that the respondents' WTP for RES ranges between 15.29€ and 17.37€, with a mean value of 16.33€/household to be to be paid quarterly as an additional charge on the electricity bill [199]. Evidently, as the importance of the revenues is high when it comes to the assessment of a project, for our calculations the mean value of the WTP will be used in the baseline scenario, while the lower and upper margins will take part in a sensitivity analysis in order to evaluate their effect on the Project's final outcome. Since the above mentioned values were calculated in 2009, we have to bring them up-to-date using the same methodology as we did in the previous steps of the analysis:

$$CPI_{2016} \Big/ CPI_{2009} = 104.150 \Big/ 100 = 1.0415$$

Hence, we calculate the following WTP in terms of the year 2016:

$$WTP_{base\ln e} = 1.0415 \cdot 16.33 = 17.01 €$$

$$WTP_{\min} = 1.0415 \cdot 15.29 = 15.92 €$$

$$WTP_{\max} = 1.0415 \cdot 17.37 = 18.09 €$$

By generalizing the above values for the whole country and by taking into account that the total amount of households in Greece, as formally identified by means of a population census in 2011, is 4134540, the aggregate annual WTP for each scenario of the Project and for the whole Greek population is estimated as follows:

$$WTP_{baseline} = 3 \cdot (quarterly\_payment) \cdot (No\_of\_households)$$
$$= 3 \cdot 17.01 \cdot 4134540 = 210985576 €/\text{year}$$

$$WTP_{\min} = 3 \cdot 15.92 \cdot 4134540 = 197465630 €/\text{year}$$

$$WTP_{\max} = 3 \cdot 18.09 \cdot 4134540 = 224381486 €/\text{year}$$

However, the energy produced by the PV power plants of the specific Project is not enough to be consumed by all Greek households. Based on the information presented in the tables 5 and 18, the expected electricity generation in the country in 2020 for the "Accelerated Economy Recovery" Scenario of the National Action Plan is equal to 72.48 TWh, while the calculated energy generated by the Project in the same year is equal to 4.7997 TWh. Therefore, the contribution of the Project to the total electricity production of the country is equal to a percentage of 6.6%. Since the Project can provide only 6.6% of the total energy production, the same percentage will be available for the Greek households to consume. Thus, the revenues of the Project should be adjusted in order to reflect the same percentage. According to this reasoning, the aggregate annual WTP that will be considered for each scenario of the Project is scaled down as shown below:

$$WTP_{baseline} = 210985576 \cdot 6.6\% = 13925048 \text{ €/year}$$

$$WTP_{\min} = 197465630 \cdot 6.6\% = 13032732 \text{ €/year}$$

$$WTP_{\max} = 224381486 \cdot 6.6\% = 14809178 \text{ €/year}$$

<u>Step 6: Calculation of the economic return of the project</u>

Having implemented all previous steps of the socio-economic analysis, we move on to the last one, which is the calculation of the social net present value (SNPV), and the social rate of return (SRR) of our Project. Based on the resulting values of the SNPV and SRR we will be able to assess the impact of our Project in respect with the society's welfare in Greece. The estimation of the aforementioned indicators will be achieved by using the same main equations but customized in a way to include all parameters considered from a social point of view. Moreover, it should be noted that even though the formulas' notation is kept the same, the actual numerical values used in the socio-economic analysis are different than the ones used in the financial one; their differences were explained in detailed in the previous steps of the methodology. Consequently, the necessary equations for our socio-economic calculations will take the following forms:

$$SNPV = \sum_{t=1}^{N} \left(\frac{-C_{own,s,t}}{(1+RSDR)^t} + \frac{NCF_{s,t}}{(1+RSDR)^t} + \frac{SV_{s,t}}{(1+RSDR)^t} + \frac{Externalities_{s,t}}{(1+RSDR)^t} \right) \Rightarrow$$
$$SNPV = \sum_{t=1}^{N} \left(\frac{\sum Social\_Benefits_t}{(1+RSDR)^t} - \frac{\sum Social\_Costs_t}{(1+RSDR)^t} \right)$$

and

$$\sum_{t=1}^{N} \left(\frac{-C_{own,s,t}}{(1+SRR)^t} + \frac{NCF_{s,t}}{(1+SRR)^t} + \frac{SV_{s,t}}{(1+SRR)^t} + \frac{Externalities_{s,t}}{(1+SRR)^t} \right) = 0 \Rightarrow$$
$$\sum_{t=1}^{N} \left(\frac{\sum Social\_Benefits_t}{(1+SRR)^t} - \frac{\sum Social\_Costs_t}{(1+SRR)^t} \right) = 0$$

where:

- N : the lifetime of the Project, equal to 24 years
- s : the number of sub-projects, taking values from 1 to 5.

- $C_{own,s,t}$: the own capital invested for the realization of sub-project s in year t, as a sum of the investment costs of all types of PV plants consisting the subproject
- $NCF_{s,t}$: the NCF of sub-project s in year t, as a sum of the $NCFs$ of all types of PV plants consisting the subproject
- $SV_{s,t}$: the salvage value of the sub-project s in year t, as a sum of the salvage values of all types of PV plants consisting the subproject
- $RSDR$: the real social discount rate
- $Externalities_{s,t}$: the aggregated annual external costs and benefits of sub-project s in year t, as a sum of the external effects of all types of PV plants consisting the subproject.

From the above mentioned equations the last parameter to be defined is the social discount rate (SDR). This parameter indicates the opportunity cost of capital from society's perspective; in other words, it reflects the social view of how future benefits and costs are to be valued against present ones. It should be noted that in a perfectly competitive economy, the social and financial discount rates coincide with each other. However, this situation is not common, since capital markets are usually characterized by distortions.

The estimation of the SDR can be achieved based on various approaches, among which the most popular ones are described briefly below:

- ***The social rate of return on private investments (SRRI) approach***

  The main concept of this method is that public investments replace private ones. Consequently, the benefits arising from the public investment should be at least as high as the ones that could derive from a private investment. In this case, the SDR is considered equal to the marginal social opportunity cost of funds in the private sector [145], [185].
- ***The social rate of time preference (SRTP) approach***

  According to this approach, the SRTP is the rate at which society is willing to postpone the consumption of a unit in the present in exchange for more consumption in the future. When implementing this method, the government should consider the welfare of both the current and future generation; in fact, an optimal planning program, based on individual preferences for consumption, should be carried out [145], [185].
- ***The weighted average approach & the shadow price of capital approach***

  Despite their rare application, these two methods are also used for inter-temporal discounting. The former approach is based on the fact that, when public investment is considered to have a displacement impact on both private investment and future consumption, the SDR could be estimated by a weighted average of the investment rate of return and the rate of time preferences. The latter approach is characterized by the conversion of investment flows into 'consumption equivalents' through an appropriate shadow price of capital; these flows are then discounted at the social rate of time preference [145], [185].

For the sake of our socio-economic calculations, the estimation of the SDR will follow the recommendations of the EU, as defined for the most recent programming period available, the period 2014-2020. Based on the SRTP approach, the European Commission suggests a real social discount rate equal to 5% for the major projects taking place in Cohesion countries such as Greece, and 3% for the rest of the Member States. Since assigning a representative social discount rate value is crucial for the results of the SCBA, the influence of this parameter on the computation of the SNPV and SRR will be checked through a sensitivity analysis. Once again, we will consider that the real SDR is equal to 5% for the baseline scenario and for all other scenarios were different parameters are checked and altered. Regarding the minimum and maximum scenarios and based on the information arising from the available literature, the real social discount rates for EU Member States will be assumed to range between 1% and 7% respectively [145], [200].

After establishing all the socio-economic parameters necessary for the calculation of the SNPV and SRR of the Project from the Greek society's point of view and assigning the corresponding conversion factors, a summary of them can be found in table 28:

Table 28: Summary of all socio-economic parameters for the calculation of the SNPV & SRR of every scenario of the Project.

<table>
<tr><th colspan="3" rowspan="2">Parameters</th><th colspan="3">Types of PV Power Parks</th></tr>
<tr><th>“L-L”</th><th>“H-L”</th><th>“H-H”</th></tr>
<tr><td rowspan="6">General Parameters</td><td rowspan="2">Project’s Lifetime (years)</td><td>Value</td><td colspan="3">20</td></tr>
<tr><td>CF</td><td colspan="3">-</td></tr>
<tr><td rowspan="2">Capacity Factor (%)</td><td>Value</td><td>19 - 19.5 - 20</td><td>21 - 23 - 25</td><td>21 - 23 -25</td></tr>
<tr><td>CF</td><td colspan="3">-</td></tr>
<tr><td rowspan="2">Real Social Discount Rate (%)</td><td>Value</td><td colspan="3">1 - 5 – 7</td></tr>
<tr><td>CF</td><td colspan="3">-</td></tr>
<tr><td rowspan="6">Social Costs</td><td rowspan="2">Investment Cost (€/kW)</td><td>Value</td><td>900-1000-1100</td><td>900-1000-1100</td><td>1100-1300-1500</td></tr>
<tr><td>CF</td><td>0.933 - 0.958 - 0.982</td><td>0.89 - 0.93 - 0.97</td><td>0.855 - 0.908 - 0.961</td></tr>
<tr><td rowspan="2">O&M Cost (% of the investment cost)</td><td>Value</td><td colspan="3">2</td></tr>
<tr><td>CF</td><td colspan="3">0.992 - 0.995 - 0.998</td></tr>
<tr><td rowspan="2">External Costs (€/kWh)</td><td>Value</td><td colspan="3">0.007195</td></tr>
<tr><td>CF</td><td colspan="3">1</td></tr>
<tr><td rowspan="14">Social Benefits</td><td rowspan="2">Revenues (€/year)</td><td>Value</td><td colspan="3">13032732 - 13925048 – 14809178</td></tr>
<tr><td>CF</td><td colspan="3">-</td></tr>
<tr><td rowspan="2">Salvage Value (% of the investment cost)</td><td>Value</td><td colspan="3">15</td></tr>
<tr><td>CF</td><td colspan="3">-</td></tr>
<tr><td rowspan="2">External Benefit I (€/kWh)</td><td>Value</td><td colspan="2">0.0161</td><td>-</td></tr>
<tr><td>CF</td><td colspan="3">1</td></tr>
<tr><td rowspan="2">External Benefit IIa (€/kWh)</td><td>Value</td><td colspan="2">0.0062 - 0.0139 - 0.0145</td><td>-</td></tr>
<tr><td>CF</td><td colspan="3">1</td></tr>
<tr><td rowspan="2">External Benefit IIb (€/kWh)</td><td>Value</td><td colspan="2">-</td><td>0.053 - 0.0879 - 0.123</td></tr>
<tr><td>CF</td><td colspan="3">1</td></tr>
<tr><td rowspan="2">External Benefit IIIa (€/kWh)</td><td>Value</td><td colspan="2">0.029037</td><td>-</td></tr>
<tr><td>CF</td><td colspan="3">1</td></tr>
<tr><td rowspan="2">External Benefit IIIb (€/kWh)</td><td>Value</td><td colspan="2">-</td><td>0.025543</td></tr>
<tr><td>CF</td><td colspan="3">1</td></tr>
</table>

At this point, the results of the SNPV and real SRR of the Project for all possible scenarios are calculated by inserting the aforementioned socio-economic parameters in the relevant formulas introduced at the "social" part of the analysis. As it was the case for the financial part too, the main scenarios examined here are the baseline, the minimum and the maximum scenario, but this time incorporating the socio-economic aspect into the calculations. All scenarios were formulated similar to the financial analysis' scenarios; for all certain parameters their standard values were considered while for the uncertain ones the most probable, the minimum and the maximum values were considered corresponding to the baseline, the minimum and the maximum scenario. All of the required calculations were executed through Microsoft Excel and the detailed numerical results can be found in Appendix B. The graphical results of the calculations are presented in figures 46 and 47 below. More specifically, figure 46 depicts the estimated findings of the SNPV, while figure 47 the ones of the real SRR with respect to the aforementioned scenarios.

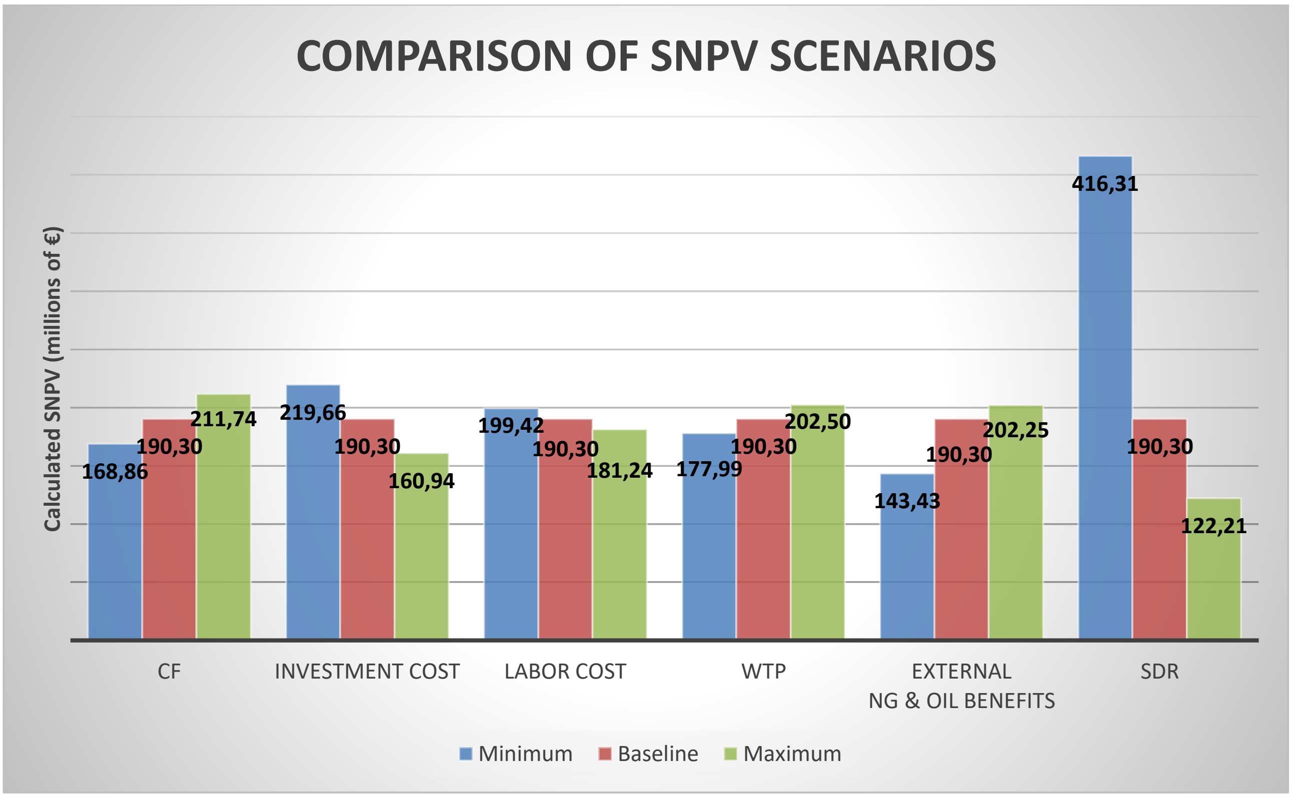


Figure 46: Socio-Economic CBA Sensitivity Analysis Results.

Comparison of the calculated NPV per uncertainty and scenario.

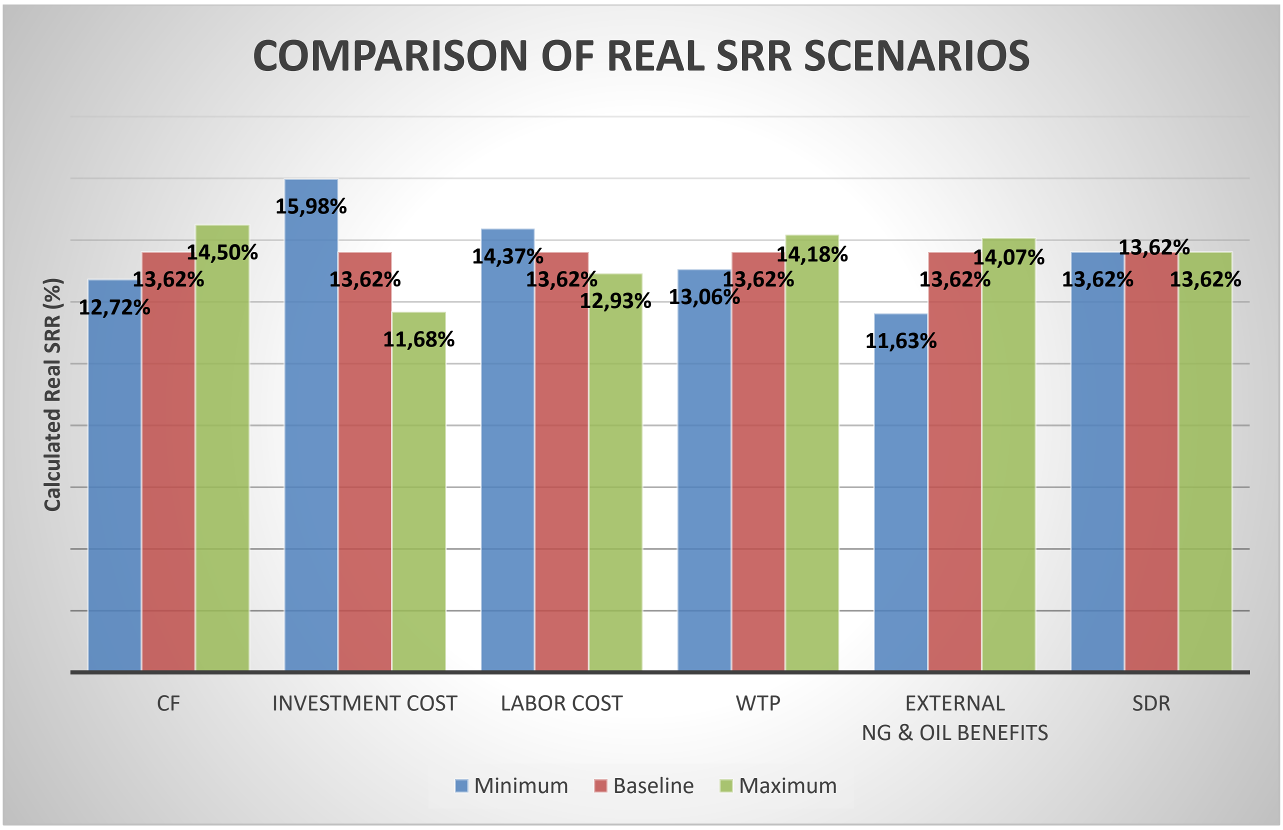


Figure 47: Socio-Economic CBA Sensitivity Analysis Results.

Comparison of the calculated Real SRR per uncertainty and scenario.

As confirmed by the SNPV and SRR calculations gathered in Appendix B and graphically presented in figures 46 and 47, the outcome of the socio-economic analysis for this Project is positive for all scenarios studied, even for the least favorable ones. Therefore, we can be sure that its successful implementation would contribute significantly to the improvement of the Greek society's welfare. This assertive conclusion derives from the satisfaction of the following factors:

- **SNPV > 0**

  The calculated SNPV value for all plausible scenarios examined in the sensitivity analysis is positive. This indicates that the Greek society as a whole will have more gain by accepting the proposed Project rather than continue supporting the existing energy landscape of the country.

- **Real SRR > Real Discount Rate**

  With regards to the real SRR, its calculated values are in the range of 11.63% - 15.98% among all possible scenarios of the sensitivity analysis. The fact that the real SRR exceeds in every scenario the value of the real social discount rate (assumed to be 5%) indicates that the sacrifice of resources for the implementation of the Project is beneficial, as far as the Greek society is concerned.

After studying the calculated results carefully, it is obvious that regarding the SNPV the most influential parameters are the social discount rate, the interrelated prices of Natural Gas & Oil and the investment costs, while the capacity factor, the WTP and the labour costs seem to have a more limited impact. For the SRR, the investment costs seem to be the most important parameter, followed by the prices of Natural Gas & Oil, the CF, the labour costs and, last but not least, the WTP. Similar to the financial analysis, the changes in the discount rate do not affect the calculated SRR by definition. Additionally, it should be mentioned that for all of the uncertain parameters examined in the sensitivity analysis, the SNPV and SRR vary following a similar pattern; a parameter that causes an increase in SNPV, causes an increase in SRR and vice versa.

Having presented our findings for the baseline, minimum and maximum scenarios, we shift our attention to each uncertain parameter and its effect on the SNPV and SRR calculations, as we did in the financial part of the thesis. In this process all uncertain parameters are considered except for the price of Natural Gas. The reason of this exclusion is that this parameter is dependent to the price of Oil, through a linear relation, which was presented earlier. Therefore, analyzing the impact of the fluctuations in the price of Oil on the SNPV and SRR of the Project is sufficient.

Based on the same methodology as the one used in our financial analysis and with the help of Microsoft Excel, the available data for each uncertain socio-economic parameter are standardized, and plotted altogether against the same SNPV and SRR graphs, for a better comparison. Figures 48 and 49 present the corresponding results. A further commentary on each uncertain parameter and its effect on the calculation of both socio-economic indicators is evident in the following section.

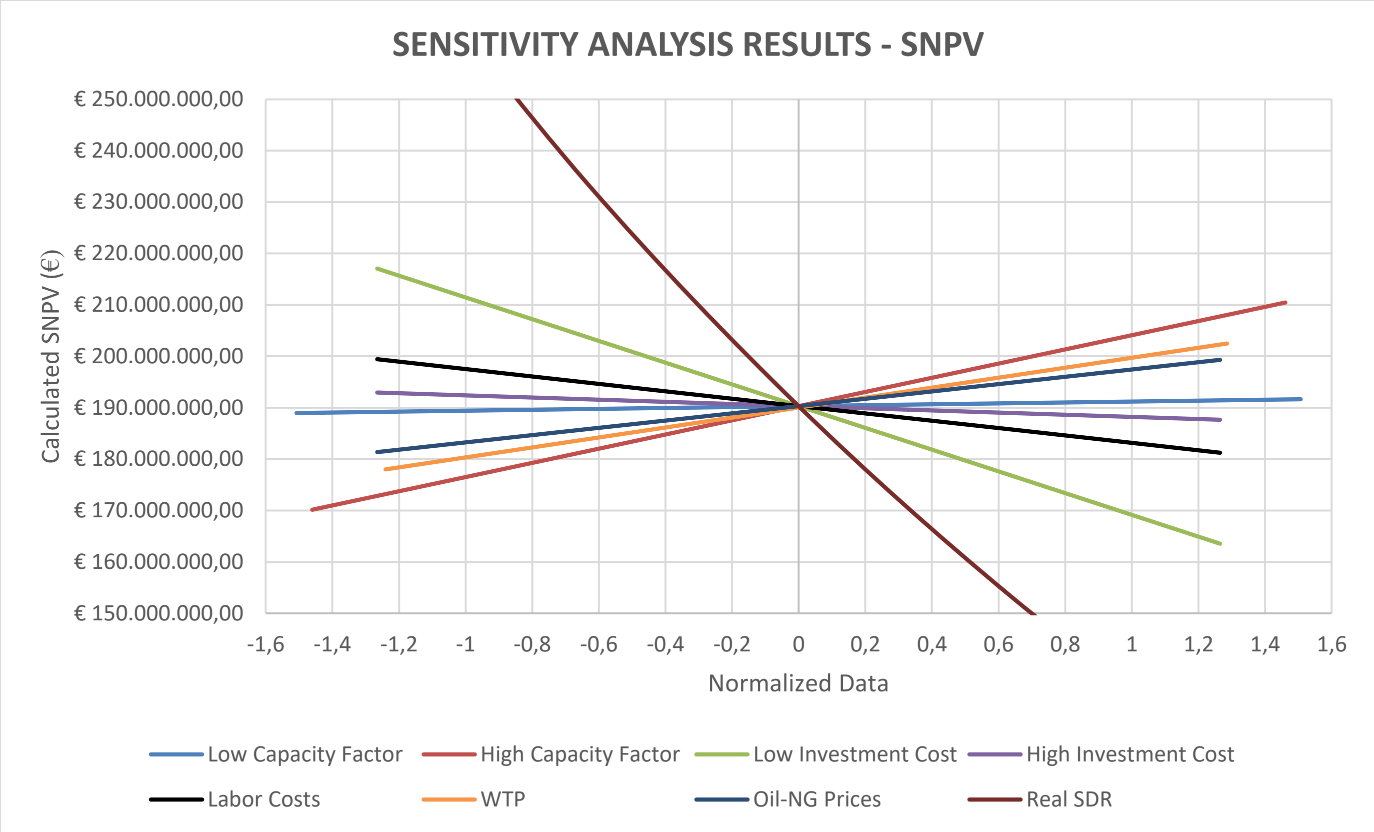


Figure 48: Socio-Economic CBA Sensitivity Analysis Results – All Uncertain Financial Parameters VS SNPV.

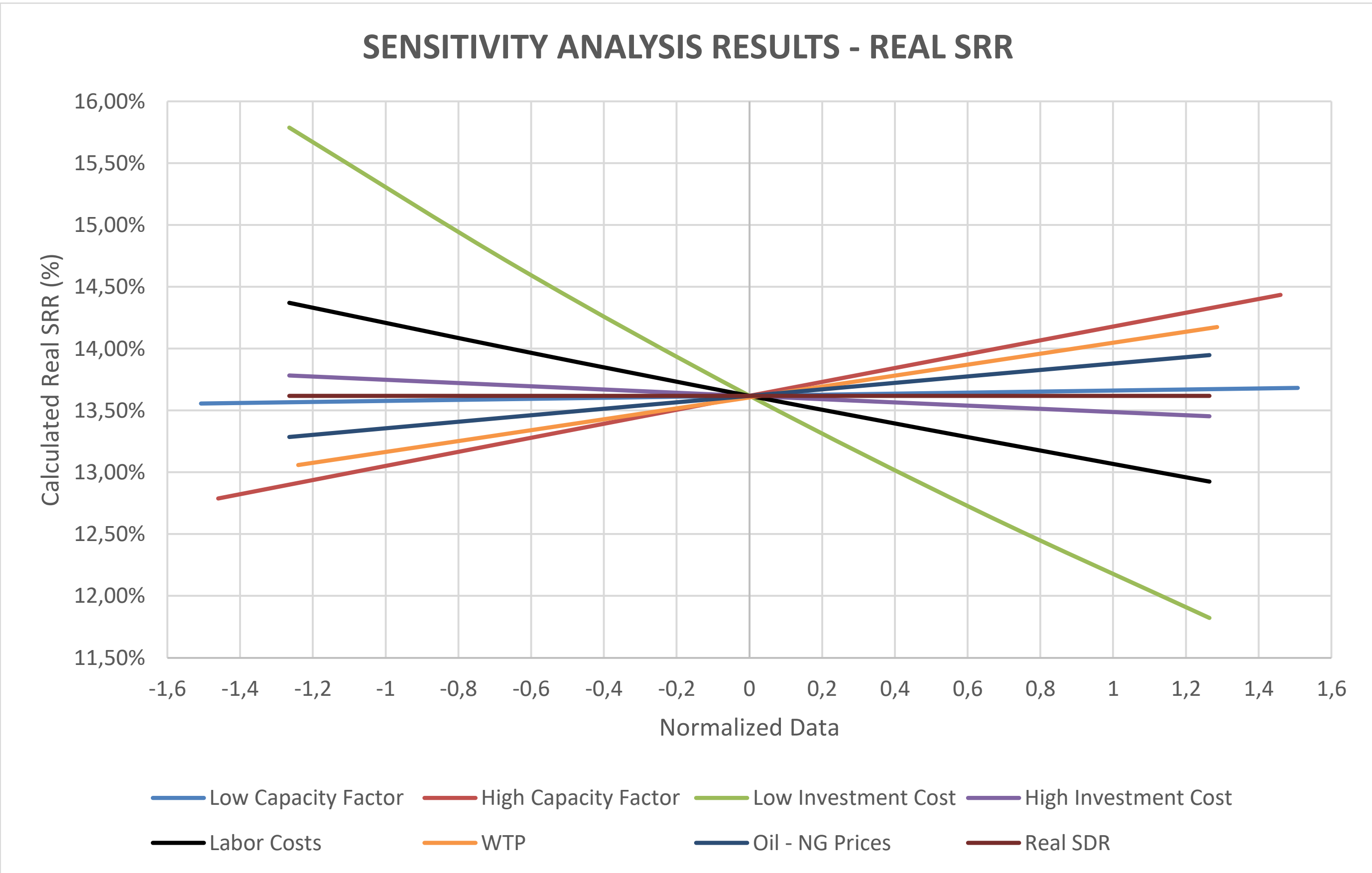


Figure 49: Socio-Economic CBA Sensitivity Analysis Results – All Uncertain Financial Parameters VS Real IRR.

In line with the financial part of the CBA, table 29 below briefly summarizes all uncertainties and their effect on the final calculations of the SNPV and SRR, from the most to the least influential ones, as emerged from the sensitivity analysis of the Project earlier. Moreover, each parameter and its impact on the calculation of both socio-economic indicators is analyzed further in the following section.

Table 29: Summary of the influence of all uncertain parameters to the SNPV & SRR calculations, presented from the most to the least significant one.

Socio-Economic Indicator	SNPV		SRR	
Relation	**Linear & Proportional**	**Linear & Inversely Proportional**	**Linear & Proportional**	**Linear & Inversely Proportional**
Parameters	High Capacity Factor	Real SDR	High Capacity Factor	Low Investment Cost
	WTP	Low Investment Cost	WTP	Labour Costs
	Oil-NG Prices	Labour Costs	Oil-NG Prices	High Investment Cost
	Low Capacity Factor	High Investment Cost	Low Capacity Factor	-

From figures 46 and 47, it is obvious that the investment cost is the most potent parameter among all uncertainties examined, confirming once again the fact that PV power plants are costly investments. According to the sensitivity analysis, the relation between the investment cost and both socio-economic indicators is linear and inversely proportional, as the higher the investment cost the lower the calculated SNPV and SRR. In line with the financial part of the CBA, the minimum scenario, where all types of PV parks show the lowest possible investment cost, has the second highest SNPV equal to 219.66 million € and the highest SRR equal to 15.98%. On the contrary, the maximum scenario, with all types of PV parks represented by the highest possible investment cost, shows one of the lowest SNPV values equal to 160.94 million € and the second lowest SRR equal to 11.68%. Regarding the low and high investment cost curves depicted in figures 48 and 49, the former parameter shows a sharper slope, which suggests a greater influence on the Project's profitability compared to the latter. As explained earlier, this is due to the bigger number of low investment PV power parks (types "L-L" and "H-L") considered for the Project. For the sake of the current analysis, investment cost mainly depends on the amount of installed energy capacity of each type of PV power plant. Since types "L-L" and "H-L" constitute the majority of PV parks considered, they contribute to a larger proportion of installed energy capacity, thus they have a greater impact on the final SNPV and SRR calculations.

With regards to the willingness to pay, its influence to the socio-economic calculations seems to be quite significant. Information retrieved from figures 46 and 47 exhibits that the higher the WTP the more beneficial the Project and vice versa. Thus, for the minimum scenario the calculated SNPV is equal to 177.99 million € and the SRR equal to 13.06%, while for the maximum scenario the aforementioned indicators take the values 202.50 million € and 14.18% respectively. The impact of the WTP on the SNPV and the SRR is noteworthy, considering its small participation to the calculations. In fact, the specific parameter is responsible only for the calculation of the annual revenues with no further involvement in any other input of the Project. However, the very limited literature available on this matter shouldn't be overlooked when judging the effect of this parameter. Observing closely the WTP's representative curves in figures 48 and 49, we can identify their similarity to the Oil and Natural Gas curves in terms of inclination, something which makes sense if we consider that both parameters relate only to the social benefits and not the social costs. However, the WTP curves are steeper compared to the conventional fuel's ones, meaning that they impose greater impact to the final calculations.

One more parameter causing significant fluctuations to the SNPV and SRR values among the different scenarios is the Oil and Natural Gas fuel prices. These conventional fuel prices affect the level of the External Benefits IIa and IIb, and therefore the level of the Project's overall Social Benefits. A linear and proportional relation characterizes the fuel prices and the socio-economic indicators; hence when Oil and Natural Gas prices increase, society's benefits increase too, resulting in higher SNPV and SRR values. The previous conclusion is confirmed by our calculations, where for the minimum scenario the SNPV is equal to 143.43 million € and the SRR takes its lowest value of 11.63%, while for the maximum scenario the SNPV is 202.25 million € and the SRR 14.07%. From figures 48 and 49, it can be seen that the curve representing the influence of conventional fuel prices on the Project's SNPV and SRR values lies between the curves corresponding to the PV parks' low and high capacity factors' influence. However, a comparison between them cannot be made directly, as the aforementioned parameters are interdependent. Capacity factors define the amount of the generated energy, which in turn determines the amount of all external costs and benefits of the Project.

Continuing the analysis of the graphs, the next important uncertain parameter is the capacity factor. Contrary to the financial, in the socio-economic CBA the capacity factor doesn't determine the revenues but the social external costs and benefits of the Project. As a result, the sensitivity analysis conducted for the capacity factor in fact provides information about the sensitivity of both socio-economic indicators to the Project's negative and positive externalities. As expected and verified from the figures 46 and 47, an increase in the capacity factor indicates an increase in the estimated SNPV and SRR values and vice versa. More specifically, for the minimum scenario the SNPV is equal to 168.86 million € and the SRR equal to 12.72%, while for the maximum scenario the corresponding values are 211.74 million € and 14.5% respectively. Comparing the low and high capacity factors' representation curves as shown in figures 48 and 49, it is easy to see that the latter has a steeper inclination, hence a greater impact on the SNVP and SRR calculations. This observation is reasonable and is attributed to the exact same reasons as in the case of the investment cost. High capacity factors indicate more energy produced per year, which in turn can be translated to greater external effects for the Project. Since the majority of PV parks considered in the analysis are located in regions with high solar potential, we understand the high impact of this parameter to our calculations.

As far as the conversion factor (CF) for labour costs is concerned, it is the parameter with the smallest influence on the Project's socio-economic viability, most probably due to the narrow selection of possible values considered in the sensitivity analysis. Based on figures 46 and 47, it can be seen that the minimum scenario results in a SNPV of 199.42 million € and a SRR of 14.37%, while the maximum scenario gives a SNPV of 181.24 million € and a SRR of 12.93%. From figures 48 and 49, it is obvious that the CF parameter has a linear and inversely proportional relation to the socio-economic indicators of the Project. This can be attributed to the fact that the CF for labour costs influences directly three main inputs of the calculations: the investment cost, the O&M cost and the salvage value. Since the first two represent costs and the last one benefits, it is obvious that an increase in the CF value causes an increase in the total costs - hence a decrease in the total benefits - making the Project less attractive for the society.

The impact of the real social discount rate (SDR) is the last one to be discussed. Concerning the SRR calculations, the parameter takes a constant value equal to 13.62% for all scenarios examined, due to its definition. However, concerning the SNPV calculations, the real SDR shows significant fluctuations. Emerging from the final form of the equation estimating the SNPV for each scenario and confirmed by figure 48, the parameter has a linear and inversely proportional relation to the SNPV; hence, the higher the social discount rate, the lower the SNPV calculated. According to figures 46 and 47, for the minimum scenario of the Project the SNPV takes its highest value equal to 416.31 million €, while for the maximum scenario its lowest equal to 122.21 million €.

Concluding the analysis of the socio-economic part of the CBA, it is worth mentioning the problem of possible "overlapping" in our calculations. According to the definition of the term, overlapping occurs when a stream of costs or benefits is likely to be or is indeed counted twice. Detecting overlapping in the SCBA is really hard, due to the high interdependence existing between the impacts of a project. In our SCBA calculations, overlapping may be evident in the values used to indicate the WTP for renewable energy, the external costs and the external benefit

III deriving from the CASES project. However, the great lack of research and literature on these topics for the country of Greece, and especially during the period of the crisis, doesn't allow us to perform more accurate calculation that could eliminate completely the phenomenon of overlapping.

6.4 Financial Vs Socio-Economic CBA

After elaborating on the results of our calculations, the current sub-chapter intends to summarize our conclusions and provide a comparison between the two parts comprising our CBA, the financial and the socio-economic part.

The final conclusion drawn from the application of the SCBA method for the case of Greece is that the implementation of large-scale PV power parks all over the country, as specified by the EU Directives, is an investment worth undertaking for all members of the Greek society. This is undoubtedly confirmed by the positive results of both the NPV and the SNPV of the financial and the socio-economic part of the CBA respectively for all possible scenarios examined. Moreover, it is reaffirmed by the IRR and the SRR of the two parts of the CBA as well, as they both exceeded the real discount rates chosen in all considered scenarios. Since the implementation of the Project will benefit both private investors and the society as a whole, the Greek government should proceed with its realization and thus help the crisis-stricken Greek economy recover faster.

Moving on to the comparison of the two parts, it is helpful to remember once again their basic difference; for the financial part only the private investor owning the Project has standing, while for the socio-economic part the whole Greek society. Therefore, in the first analysis only the market prices are important to consider, in contrast to the second one where shadow prices and opportunity costs are taken into account along with all the possible social externalities that may have an impact on society's welfare.

Based on the results of both parts' calculations, we can report that for the financial CBA the calculated NPV values range between 22.88-77.46 million € and the IRR between 4.13%-6.97%. However, with regards to the socio-economic CBA the corresponding ranges are much wider, taking values between 122.21-416.31 million € for the SNPV and 11.63%-15.98% for the SRR. From the aforementioned values and the detailed results presented in Appendices A & B, it is obvious that the socio-economic analysis yields more gains compared to the financial analysis, a situation that is verified for both financial indicators in every common scenario examined. In addition, the socio-economic analysis appears to be superior to the financial not only in the common scenarios but in all scenarios considered in the thesis.

The overall more efficient performance of the socio-economic CBA compared to the financial one is a result of their different perspective. As it was mentioned earlier, the social CBA accounts not only for the financial profitability of the Project but also for all external costs and benefits affecting the society as a whole. In our Project, the main externalities leading to the better SCBA results are the following: the external benefit I, representing the avoided fuel costs due to domestic lignite's substitution; the external benefits IIa & IIb, indicating the lower dependence on natural gas and oil imports as well as the higher security in energy supply; the external benefits IIIa & IIIb, standing for the reduced environmental impacts; and the influence of the Greek labour market, which was adjusted for all market imperfections with the use of proper conversion factors.

6.5 Comparison with other RES technologies in Greece

The positive results coming from the conduction of the SCBA to PV energy for large-scale solar applications in Greece during the crisis, reasonably stimulate curiosity about how good the rest of the RES technologies could perform under the same circumstances. Unfortunately, after intensive research in the available literature, no other similar studies have been performed for the difficult period of the economic crisis taking into account not only the financial but also all possible social externalities, except for one. Written by Ioanna Barouni, the thesis report "Transition of Wind Energy in Greece: A Social Cost-Benefit Analysis" investigates the impact of a large-scale wind energy implementation on Greek population's welfare during the Greek debt crisis. The wind energy target studied is the one set by the European Renewable Directive 2009/28/EC and the Greek National Renewable Energy Action Plan (NREAP) for 2020, while its appraisal is accomplished via the execution of the same "SCBA" methodology [183].

Comparing the two studies, we can report one significant similarity. The findings of both confirm that the realization of the NREAP targets corresponding to wind and solar PV energy would result in positive net social benefits for the Greek society. This suggests improved socio-economic status for Greece and positive social gains for the citizens. More specifically, all scenarios formed and evaluated for both parts of the SCBA of the two studies (private and social part) showed a positive outcome, with the socio-economic part being more beneficial as an investment in all cases. Consequently, the case-studies proposed by both theses are presumed worth undertaking, as both the private investor and the whole Greek society would eventually be better off from their implementation [183].

Moving on to the differences, it can be noticed that the magnitude of the results between the two studies vary considerably. To be more precise, the NPVs of the financial parts of the two SCBAs fluctuated in the range of 3.68-6.11 billion € for wind and 22.88-77.46 million € for solar PV energy, while the corresponding IRR values ranged between 10.88%-16.73% and 4.13%-6.97%. The same phenomenon is also apparent in the socio-economic parts of the two studies; the SNPVs took values between 5.03-12.85 billion € for wind and 122.21-416.31 million € for solar PV energy, while the corresponding IRRs were calculated in the range of 14.74%-20.45% and 11.63%-15.98% [183].

Concluding, it could be argued that wind energy transition seems as a more beneficial investment compared to solar PV for Greece at the time being. However, we shouldn't forget the different "side conditions" and assumptions made in each research that don't allow for straightforward comparisons, e.g. the higher target to be achieved by wind energy or the shorter lifespan of the solar PV case-study. In any case, one thing is concluded for sure; both studies present optimistic results for RES technologies applied in the crisis-stricken Greece, thus further investigation on the matter is required.

Chapter 7: Conclusions & Reflections

The present Thesis attempted to evaluate the financial and socio-economic impact of a potential solar PV transition in Greece during the period of the Greek debt crisis. The analysis started on a more general basis by introducing the Reader to the crisis and its unfavorable consequences to the Greek economy. Subsequently, it presented the Greek energy sector, focusing on renewable energy resources and how their deployment could be the solution to the country's economic recession. The analysis was next narrowed down to a case-study for the implementation of large-scale solar PV power plants in Greece with respect to the country's national and European energy commitments by 2020. The overall value of the proposed case-study was assessed through the conduction of a Social Cost Benefit Analysis (SCBA), which was performed in two distinctive parts: the financial part concerning only private investors, and the socio-economic part including the opinion of the whole Greek population. The positive results of both SCBA parts, affirmed the initial speculations; achieving the solar PV targets set by the EU and the Greek State by the end of 2020 could actually improve the current financial and socio-economic situation of Greece.

In this final chapter our overall conclusions and reflections are discussed. We begin with presenting all findings arising from the conducted SCBA and with analyzing their meaning in relation to the thesis's objective by giving specific answers to the original research questions. After highlighting the main conclusions of the research, we proceed with giving policy recommendations and suggestions for future work on the field. Last but not least, we conclude with some reflections on the delivered study, underlying its strong and weak points and mentioning its impact on a personal level.

7.1 Conclusions by Research Question

With the completion of the SCBA analysis we are in position to provide sufficient answers to all research questions which were set at the beginning of the current thesis. The aforementioned questions are answered throughout the body of the report and are gathered below:

- ***What is the European Sovereign Debt Crisis and how did it influence the economic state of Greece?***

The much-discussed term "European Sovereign Debt Crisis" refers to the multi-year debt crisis that has been taking place in the European Union since the end of 2009. A number of causes acting simultaneously that period, such as the financial crisis of 2007-2008 and the real estate market crisis, combined with the misguided fiscal policies adopted by several Eurozone Member States, made it impossible for Greece, Portugal, Ireland, Spain and Cyprus to repay their government debt or to bail out their heavily indebted national banks without the assistance of third-party financial institutions. This situation resulted in a crisis of confidence towards European businesses and economies [2], [3], [4].

Focusing on Greece, since 2009 the adverse consequences of this situation were more than evident with the country trying to handle unsustainable government debts and trade deficits. Up to this day, several Greek governments tried to overcome the economic recession by receiving loans issued by the EU and the IMF and by imposing insufferable austerity measures to the Greek people.

- ***What is the current status of the Greek Energy Sector and how is this sector affected by the economic crisis?***

An in depth analysis of the Greek energy situation requires the studying of the behavior of basic supply and demand fluctuations for all energy sources. The two terms most accurately describing these varying energy data are total primary energy supply and total final consumption [33].

With regards to the total primary energy supply (TPES), this was equal to 27 million tons of oil equivalent (Mtoe) in 2010, showing an 8.2% decrease comparing to 2009 and an 11.1% decrease comparing to 2008, in contrast to the period 1990-2008, when it increased on average by 2% per year with the corresponding increase of the GDP being more than 3%. At 2010, the country's energy needs and the entire indigenous production relied by one third on domestic sources such as lignite and renewable energy, and by two-thirds on oil and natural gas almost entirely imported from abroad. Among them, oil still remains the most prevalent energy source in Greece, with a declining share in TPES from 77% to 52% between the years 1973 and 2010. Lignite comes next with a share of 27% of TPES in 2010 and plays the leading role in electricity production. The third biggest contributor in the energy sector with a fast growth over the last decades is natural gas, accounting for 12% of TPES in the same year. According to the aforementioned data, the total share of fossil fuels to the TPES in 2010 is equal to 91%, one of the highest percentages among the IEA members. With regards to renewable energy, energy supply from such sources isn't sufficiently widespread yet. More specifically, biofuels and waste provided 4%, hydropower 2%, solar and wind energy less than 2% of TPES in 2010 [29].

Regarding total final consumption, this was equal to 20.6 Mtoe in 2009. As a result of the economic crisis, TFC follows a similar trend to that of TPES. More specifically, in the period 1990-2007 TFC increased on average by 2.5% annually but from 2008 to 2009 there was a significant decrease of 2.8%. Once again, oil is the most important fuel with a share of 65% of TFC in 2009, a share that remains quite stable over the years. The dominance of oil is obvious in all energy consumption sectors, bringing Greece in the first place in oil usage among the IEA members and in the second place among the OECD members. The second most common energy source is electricity with a rising contribution of 17% in 1990 to 23% of TFC in 2009. This share is divided between the service sector with 41%, the residential sector with 33% and the industrial sector with 26% of the total consumption of all electricity. The rest 12% of TFC is covered by other energy sources, with natural gas and coal used in industry and renewable energy in individual households for heating water [29].

As the thesis concentrates on RES and especially solar energy, it is essential to take a deeper look at their contribution to the Greek energy landscape. Over the past two decades they showed a stable growth, accounting for an average amount of 5% - 6% of the country's TPES. This share reached the remarkable percentage of 7.5% in 2010. However, since 2010 a stagnation in RES development can be observed, attributed to the Greek debt crisis troubling the country. Due to this unstable situation, the 2010 energy data presented already are the most reliable recent data that could be retrieved by the time of conduction of the thesis [29].

- ***With regards to Renewable Energy Sources (RES), which are the main national and international targets of Greece and at which extend are they achieved up to this day?***

The depletion of conventional energy sources, the increasing demand for energy consumption and the limited alternatives of indigenous fossil fuels for energy production made Greece realize the importance of Renewable Energy Sources (RES) and commit to national and international agreements that supported their deployment over the years.

The first international energy targets that Greece committed to follow were set by the Kyoto Protocol in 1997. This is an international agreement, which commits its parties by setting binding greenhouse gas (GHG) emission reduction targets. According to the protocol and during its first commitment period (2008-2012), Greece agreed to reduce the maximum amount of its GHG-emissions by 8%, comparing to the corresponding amount of 1990. In December 2008, Greece took a step further by agreeing to reduce its emissions by 4% more till 2020, comparing to the ones of 2005. Currently, the country is in line with all the international conditions of the Kyoto protocol, thanks to its renewed energy policies and the ever increasing awareness of the Greek people [39], [41].

The second important set of international RES targets Greece committed to implement were set by the Renewable Energy Directive 2009/28/EC, which was compiled by the European Commission and signed by the EU members in 2009. According to this Directive, the EU commits itself to reach a 20% share of RES in final energy consumption and a 10% share of RES in transport by 2020. Moreover, every Member State has to define and fulfill individual targets for the overall share of RES in energy consumption. As a Member State taking part in the Directive, Greece committed to increase its renewable share from 6.9% in 2005 to 18% in 2020 [1].

As already mentioned, the European Renewable Energy Directive 2009/28/EC indirectly created the need for every Member State to modify its national legislation so that the final energy targets required could be achieved. For Greece such alterations were transposed into the national legislation via the Law 3851/2010, which was adopted in 2010. According to this law, by the end of 2020 RES should contribute a minimum share of: 20% of the gross final energy consumption, 40% of the gross final electricity consumption, 20% of the final energy consumption for heating and cooling purposes and 10% of the final energy consumption for transportation. The corresponding policies and regulations were cited in detail in the National Renewable Energy Action Plan (NREAP), a report compiled in November 2009. The action plan examines three scenarios with differing results for final energy consumption, renewable energy contribution and capacity. For solar PV technology, the three proposed scenarios impose a total installed capacity of solar PV equal to 0.7GW (Reference scenario), 2.2GW (Compliance scenario) and 2.9 (Accelerated scenario) by 2020. According to the statistical data of the Hellenic Association of Photovoltaic Companies, the total PV capacity installed in Greece in 2013 was equal to 2.63 GW. Apparently, the growth of solar PV technology was so rapid that two out of the three scenarios proposed by the NREAP have already been fulfilled seven years earlier than predicted [29], [42], [43], [44].

- ***What is the present status of the Greek Solar PV Sector and what is the impact of the economic crisis on it?***

Although the Greek solar PV sector developed fast during the last decade, the future growth of the technology in general and of the PV power stations in particular is jeopardized, as the market is experiencing a serious standstill. Unfortunately, several reasons deriving from the economic crisis contributed to the current recessive situation.

To begin with, since mid-2012 significant reductions have been done in the guaranteed selling prices of electricity (FITs) generated by RES, along with the total abolition of photovoltaic subsidies, which used to facilitate such investments. In addition, a temporary tax ranging between 25% and 42% has been imposed to all operating PV power plants, making them unattractive ventures to investors. Regarding the energy institutions involved, the Operator of Electricity Market responsible for the general function of the electricity market in Greece started showing serious deficits. The unfavorable status of the sector has been worsened even more by freezing the licensing procedures of new solar PV power stations, an action decided by the government in August 2012 and put into effect in May 2013 [92].

Talking about the status of the Greek solar PV sector, it is worth mentioning the pioneering initiative of the project called “HELIOS”, which was introduced by the Greek government. Its primary objective was the installation of PV power stations on Greek land and, subsequently, the export of the produced energy to countries of Northern Europe (mainly Germany). The profits of the exports were intended to be used for paying back part of the country’s public debt. The duration of the project was planned to be four years; in the first year 2GW of PV would be installed, in the second 4GW, in the third 7GW and in the fourth 10GW. Despite being originally discussed in 2012, the realization of the project was obstructed by the crisis and little progress has been made ever since [90], [91].

- ***What is the case-study under evaluation by the current thesis?***

This thesis focuses on the following case-study, which constitutes the so-called “Project”: the implementation of solar PV power plants of large-scale for utility reasons in Greece during the debt crisis, with respect to the country’s national and European energy commitments by 2020. According to the Greek National Renewable Energy Action Plan (NREAP), the solar PV capacity expected to be installed in Greece by the year 2020 varies, depending on three different proposed scenarios: the Reference, the Compliance and the Accelerated Economic Recovery scenario. Based on the official data recorder by the Hellenic Association of Photovoltaic Companies, the total PV capacity installed in Greece in 2013 was equal to 2627 MW. As the corresponding capacity has already exceeded the estimations of the Reference (0.7GW) and Compliance (2.2GW) scenarios, our Project adopts the target set by the Accelerated Economic Recovery scenario, imposing 2.9GW of solar PV capacity installed in Greece by the end of 2020. Setting the project’s target to 2900 MW and knowing that 2627 MW have already been achieved, it is assumed that the rest 273 MW will be covered only by large scale new-built PV power plants. At this point, it should be underlined that the solar PV systems investigated by the thesis are the ones intended for utility use not domestic. Next, it is presumed that the realization of the new PV installations will be distributed equally throughout the coming period of 5 years (2016-2020), resulting in the addendum of 54.6 MW of PV capacity to be installed on an annual basis to meet the NREAP's target [42], [87]. With regards to their operating location and subsequent capital cost, it is supposed that the proposed new PV plants will fall in one of the following categories:

- "L-L" PV plants (Low solar potential, Low infrastructure cost)
- "H-L" PV plants (High solar potential, Low infrastructure cost)
- "H-H" PV plants (High solar potential, High infrastructure cost)

This additional PV capacity of 54.6 MW will be achieved by installing a mix of the aforementioned "L-L", "H-L" and "H-H" PV plants per year. To reflect the effect of the economic crisis, it is assumed that "L-L" and "H-L" plants will be realized first, being the most affordable installations, while the most capital intensive "H-H" plants will follow. The total PV capacity added per year represents one "sub-project" of the major "Project" and it is assumed that each year one "sub-project" is completed. Its operation starts in the year following its construction, with a total lifespan of twenty years, from erection to disposal. Therefore, the economic lifetime of our major Project begins in 2016 with the erection of the first sub-project and ends in 2040 with the end of the last sub-project's lifetime.

- ***Which is the methodology chosen for the assessment of the case-study and how is it implemented in our case?***

The methodology chosen for the appraisal of the case-study presented previously, is the Social Cost Benefit Analysis (SCBA). The latter term refers to a feasibility study that investigates the viability of a policy or project from the society's point of view. In other words, a SCBA sums up all costs and benefits arising from a proposed policy or project and determines whether its implementation can improve the welfare of society as a whole. The performance of the SCBA when applied to RES projects is the same as when applied to any other kind of policy or project. In order to consider all relevant financial and social impacts, the procedure needs to be completed in two basic parts: the financial and the socio-economic part [110].

Beginning with the execution of the financial CBA, we considered all costs and benefits affecting the profitability of the proposed case-study from the individual point of view of a private investor. These costs and benefits are known as internal and in the case of energy projects as ours, costs are the investment costs, operation and maintenance costs, fuel costs, taxes, insurance, etc., and benefits are the investor's profits from selling the produced energy. Having identified the aforementioned impacts, we moved on assigning them with monetary values. Using the financial parameters of the crisis-stricken Greek economy, we proceeded with the calculation of the Net Present Value (NPV) and the Internal Rate of Return (IRR) of the investment by applying the discounted cash flow methodology. From the final results of the financial part, we concluded that the proposed case-study is worth undertaking by a private investor [119], [120].

Next, the socio-economic CBA was conducted, where we took into account the impacts that appraise the project's contribution to the welfare of a region, not as a private investor his time but from the whole society's point of view. These costs and benefits are called external (or externalities) and they arise when the social or economic activities of one group of persons have an impact on another group and that impact is not fully accounted, or compensated for, by the first group. Examples of such impacts are climate change, environmental pollution, damage of human health, security of fuel supply, depletion of resources, employment, etc. Since externalities are difficult to identify and quantify, we used the method of shadow pricing to reflect their real value to society. The exact guideline used to perform shadow pricing, was the one suggested by the European Commission itself, since Greece is part of the EU. With a similar methodology to the financial part, the Social Net Present Value (SNPV) and the Social Internal Rate of Return (SIRR) were finally calculated, defining the socio-economic (hence, the overall) viability of the case-study [121], [122].

At this point, it is important to mention that for both parts of the SCBA, a baseline scenario, where all parameters were given their most probable values, was examined initially. However, after that a sensitivity analysis was performed to check the response of our results to uncertainties.

- ***Which conclusions are drawn by the conduction of the SCBA to the case-study under evaluation?***

The final results from the application of the SCBA method for the case of Greece were positive for both the NPV and the SNPV of the financial and the socio-economic part of the CBA respectively for all possible scenarios examined. Moreover, the IRR and the SRR of the two parts of the CBA, both exceeded the corresponding real discount rates chosen in all different scenarios.

Comparing the financial and the socio-economic part of the SCBA, it was obvious that the latter yielded more gains compared to the former, a situation that is true for both financial indicators (NPV & IRR) in every common scenario studied. The overall more efficient performance of the socio-economic CBA compared to the financial one can be attributed to their different perspective; the social CBA accounts not only for the financial profitability of the case-study but also for all external costs and benefits affecting the society as a whole.

- ***Could the fulfillment of the national RES target for Solar PV Energy by 2020 contribute to the improvement of the Greek people's welfare during the period of the crisis?***

Addressing all previous questions in depth, assisted us in collecting all information necessary to give a definite answer to the primary research question of this thesis.

Based on our SCBA findings, it could be argued that the implementation of large-scale PV power parks in Greece during the crisis, with respect to the solar energy targets specified by the EU Directives and National Laws, is an investment worth undertaking that would bring several social gains to the Greek society. More specifically, a potential realization of the proposed case-study would make the whole country benefit from the avoided fuel costs of the only indigenous fossil fuel-lignite, the decreased dependency on imported natural gas and crude oil, the reduced environmental pollution and the creation of new job opportunities. Since the implementation of the examined case-study could be advantageous for both private investors and the society as a whole, the Greek government should proceed with its realization and thus help in the faster recovery of the crisis-stricken Greek economy.

7.2 Policy Recommendations

Apparently, the theoretical affirmation that meeting its national and international solar PV goals by building large-scale PV power plants till 2020 is not sufficient for Greece to put in motion the realization of such a plan. As it was evident from the research conducted, the energy policies adopted so far by both Greek and European policy makers show multiple weak points, which, if improved, could initiate new investments in the energy sector and sustain the already existing ones.

Concerning the Greek government and the rest of the Greek policy makers, a first recommendation would be to update and enhance the supporting incentives towards Renewable Energy projects, such as subsidies and Feed-in Tariffs (FITs), in order to attract more private investors. Of course such an action is expected to have an undesirable effect on public spending as well; the higher the provisions granted by the State, the higher the governmental expenditures. However, the financial and social gains deriving from such investments are much more important compared to the losses. From a pure financial point of view, a successful investment normally has high revenues, which in turn can yield revenues to the State through proper taxation. Furthermore, from a socio-economic perspective, benefits such as savings from decreased consumption of the only indigenous fossil fuel-lignite, savings from less natural gas and crude oil imports, reduced environmental pollution and decreased unemployment could compensate for the additional governmental spending in the long run.

Another recommended policy improvement addressed to the Greek authorities is the rearrangement of the responsibilities assigned to the public and private actors involved in the realization of a RES project. Despite the efforts of the State and the measures already implemented, the procedures necessary for the approval and final construction of a RES project remain complicated, discouraging new investors to proceed. In addition, the still existing bureaucracy is making things worse by causing delays in RES projects' execution and thus should be eliminated the soonest possible.

One more essential recommendation that could boost investments in RES projects is the raising of the Greek society's awareness regarding renewable energy's advantages, which would eventually result in their wider acceptance by the public. Therefore, the Greek government should take measures to provide proper education to its people on energy issues and renewable energy technologies. This could be achieved with the issuing of reliable publications, consumer guides and technology related fact sheets by both governmental and non-governmental actors and with the collaboration of supplying companies, as well as with the publishing of relative information campaigns transmitted through mass media such as television, newspapers, magazines, and leaflets. Related groups such as engineers, local administrative authorities and technical chambers can also contribute to the spreading of knowledge via their own communication paths. Action is also required to prevent or overcome local opposition related obstacles. Issues like these could be resolved by allowing the local communities affected by the realization of such projects participate directly in the decision process or get rewarded from choosing RES to conventional energy.

With regards to European polices' improvements, we could suggest the re-evaluation of the targets set for RES in general and solar PV energy in particular, in order to come up with more realistic ones. At the time being a great mismatch can be observed; solar PV energy has already reached the committed goals for two out of the three Economic Recovery scenarios compiled, while the rest of the renewable sources are falling behind significantly.

In addition, the EU national governments could consider applying the "polluter pays" principal on conventional power plants. According to this practice, those who produce pollution should bear the costs of managing it to prevent damage to human health or the environment. This way polluters would be obliged to compensate society for all the social costs resulting from the use of fossil fuels for electricity generation.

Last but not least, given that the Greek economy is still in recession, a different approach to the Greek debt crisis could be discussed between the country and its creditors to give a reasonable solution to the problem. Unfortunately, despite the loans received and the state reforms implemented so far, the current economic status of Greece doesn't create an attractive environment for people to invest with confidence in any kind of project.

7.3 Suggestions for Future Research

Having analyzed the conclusions of our study point by point, it becomes evident that certain financial and socio-economic aspects require further investigation in order to provide more reliable information for future SCBAs. In this manner such analyses will be able to achieve more accurate results in the future, which in turn will enhance their credibility as decision-making tools for the assessment of new energy projects and policies. In this context, our study showed signs of deficiency mainly with regards to the socio-economic part of the CBA and the externalities that had to be considered.

To begin with, all available studies referring to the externalities of Renewable Energy Sources in Greece were quite outdated. More specifically, the Greek national projects of ExternE and CASES, based on which the external costs and the external benefit III of our Project were calculated, were conducted between the years 1991-2005, with the latter being last updated in 2008. As a result, the actual effect of crisis on these externalities is not fully represented. Therefore, a further investigation on the up to date information on this matter would be a very useful addition to this research.

Except for the updating, the enrichment of the non-monetized externalities of solar PV energy in Greece would be very helpful too. To be more precise, benefits such as the increased security of energy supply and costs such as the integration costs of PV energy to the existing electricity grid can make a significant difference in the evaluation of a PV project. The impact of the aforementioned externalities is greater especially for countries like Greece, that are characterized by extensive conventional fuel imports and obsolete energy-generating installations.

Additionally, the conduction of more studies about the willingness of the Greek consumers to pay for PV energy is advised. The lack of adequate information on this aspect consists a major limitation for a SCBA analyst and can easily compromise his results, if we consider that all social revenues of a project derive from the selected WTP value.

The last suggestion of the thesis concerns not only Greece but all members of the European Union. As it was presented and followed, the European Commission has already published a methodology for the evaluation of new investments in its territory, including energy projects. However, a lot of the method's individual steps are abstract. Therefore, it would be beneficial to make the proposed guidelines more specific and uniform within the EU, in a way that every member can apply the method under the same standards and compare the results effortlessly.

7.4 Reflections on the Thesis

Approaching the end of this thesis, it is worth summarizing our general reflections on the research conducted. In the following sub-chapters, the strengths and weaknesses of our analysis will be discussed and general comments on the conclusions conducted and the personal gains of the work performed will be made.

7.4.1 Innovative Aspects

With regards to the innovative aspects of this report, the performance of a SCBA for large-scale PV power plants in the crisis-stricken Greece, with respect to the committed national and international RES targets till 2020, undoubtedly adds significant value to the scientific literature available on this specific field.

From the information gathered during the conduction of the analysis, it was evident that the existing bibliography dealing with the implementation of solar PV energy – and especially with large-scale PV power installations - in Greece is extremely poor. The relevant publications available focused their research on three main topics: the financial assessment of solar PV projects realized in Greece, the social externalities of PV technology in the country meaning only the environmental benefits, and the Greek consumers' willingness-to-pay (WTP) for renewable energy in general. Starting with the first type of reports identified, an adequate number of those were reviewed. However, all of them performed only the financial part of the SCBA, evaluating the profitability of the proposed energy projects only from the private investor's point of view. Hence, none of them considered any social aspects and the conversion of their market prices to accounting prices by the use of appropriate conversion factors. Moving on to the second type of reports read, even though the number of studies referring to the social externalities of solar energy in Greece was satisfactory, the matter was approached either on a theoretical level or by considering only environmental benefits, omitting all other social externalities included in this thesis. Nevertheless, we could detect a few reports that, except for the environmental benefits, investigated the relation of employment to renewable energy projects too. As far as the last type of identified reports is concerned, the Greeks' WTP for renewable energy in general was studied only by one published article, while no research could be found on the corresponding WTP for solar PV energy in Greece.

One more significant innovation of the current research compared to the already existing ones is that it evaluates the costs and benefits of the proposed case-study in the period of the Greek debt crisis. Therefore, all financial and socio-economic factors used as inputs for the calculations of both parts of the SCBA are as updated as possible, reflecting the negative influence of the economic turmoil.

At this point, we should refer to the only one similar study which was performed for the difficult period of the economic crisis taking into account not only the financial but also all possible social externalities. Written by Ioanna Barouni, the thesis report "Transition of Wind Energy in Greece: A Social Cost-Benefit Analysis" investigated the impact of a large-scale wind energy implementation on Greek population's welfare during the Greek debt crisis. The wind energy target studied was the one set by the European Renewable Directive 2009/28/EC and the Greek National Renewable Energy Action Plan (NREAP) for 2020, while its appraisal was accomplished via the execution of the SCBA methodology.

Concluding, the current thesis consists a valuable addition to the existing scientific literature, since it is the first complete SCBA assessing an actual national solar energy target and the second one evaluating a national RES target, according to the evaluation guidelines proposed by the European Commission and under the unfavorable socio-economic conditions imposed by the crisis.

7.4.2 Limiting Aspects

As in any research, during the conduction of the current thesis several difficulties and limitations were encountered, attributed either to the lack of adequate data/knowledge or to the restrictions imposed by the SCBA methodology itself. At this stage it is important to remember that acknowledging the limiting aspects of our work is a necessary process with main purpose to assist researchers on the field overcome the same obstacles and provide more accurate results in the future.

The first difficulty emerged as soon as the case-study was defined. Due to the limited time available for the realization of this work, the initial formation of the case-study in terms of types of PV parks to be installed, proper installation location, corresponding solar potential and infrastructure costs was trusted on the experience of experts on the field. Under different circumstances, special software packages could have been used to determine a more optimized allocation of the large-scale PV plants throughout the Greek landscape.

Moving on to the financial part of the SCBA, the identification and subsequent monetization of the costs and benefits of the "Project" was not easy to perform. Several inputs to our analysis, such as amounts of loans granted by the Greek banks, interest and discount rates, could not be found due to the general lack of data related to the economic crisis or due to confidentiality. To resolve this issue, we reached for the help of specialists and to reflect the uncertainty of the economic figures assumed, a sensitivity analysis was performed for each of them at the end of the calculations.

With regards to the socio-economic part, the identification and quantification of external costs and benefits was even harder. To begin with, all published studies referring to the environmental externalities of renewables in Greece were relatively obsolete. Specifically, the Greek national projects of ExternE and CASES used for our calculations were carried out in the period 1991-2005, with the latter being last updated in 2008. Hence, the actual impact of the economic crisis wasn't fully contemplated in that part of the analysis.

One more delicate social input was the Greek society's willingness-to-pay (WTP) for solar PV energy. The importance of this input is significant, considering that it consists the base for the calculation of the revenues of the SCBA. Unfortunately, its value had to be retrieved based on one research indicating the Greek people's WTP for RES in general. To check on the robustness of this assumption two actions were taken: studies examining other nations' (but similar to Greece) WTP for RES were reviewed and a sensitivity analysis of this externality was performed.

Another difficulty encountered in the conduction of the social SCBA was the assigning of proper values to the conversion factors (CFs), the multipliers used to convert market prices into shadow prices. According to the European Commission's methodology, the issuance of CFs for every sector should be done individually by each Member State and it is necessary for the evaluation of potential projects and policies on a national level. Unfortunately, such CFs are not published by the Greek State. Similar difficulties also arose in the implementation of the standard conversion factors (SCF) method. As explained in chapter 6, the estimation of these factors depends on the country's relevant taxes on imports and exports, which are considered as confidential data and thus couldn't be used for the purposes of this study. In order to proceed, for the costs and benefits that had to be converted to shadow prices with the use of a sector specific CF or the SCF approach, we assumed SCF to be equal to unity.

From a general point of view, the omission of certain costs or benefits could be stated as an additional weak point of the current analysis. Benefits such as the increased security of energy supply and costs such as the integration costs of PV energy to the existing electricity grid can play a decisive role in the evaluation of a PV project, especially for countries like Greece, that depend highly on fossil fuel imports and have an old electricity generation network. However, both overlooked effects were partly reflected in the final calculations via the sensitivity analysis of scenarios with varying oil and natural gas prices and as a part of the investment costs of all solar PV park types respectively.

Except for overlooking, overlapping, which is the double counting of costs or benefits, is also a limitation of the present SCBA. Generally speaking, the detection of overlapping in SCBAs is really hard, due to the high interdependence existing between the impacts of a project. In our case, overlapping may have occurred in the values used to indicate the WTP for renewable energy and the environmental externalities deriving from the CASES project. However, the lack of information and research on these topics for Greece during the crisis made overlapping inevitable.

Focusing on the limitations of the SCBA methodology, one restricting factor lies in the way of calculating the net benefits of a project itself. Due to certain constraints in time, theory, data, analytical resources, or experience it may be impossible for an analyst to value all these costs and benefits in terms of money. Another risk is that the SCBA methodology can be easily biased by the analyst, who could omit certain impacts of a project or police (positive or negative) or use proper discount rates in order to manipulate the results of the study and influence the final decision of the relevant authorities or even the public opinion. One last limitation worth-mentioning is that the SCBA focuses on the efficiency of a project or policy. Although efficiency is almost always one very considerable goal in policy assessment, other goals such as equality of opportunity, equality of outcome, expenditure constraints, political feasibility, and national security may be as, or even more, important. Therefore, the SCBA should be used to provide one more input to the public decision-making process and thus to make recommendations, not final decisions [111].

7.4.3 Concluding Reflections

In the present thesis we performed a Social Cost Benefit Analysis (SCBA) in order to assess the socio-economic consequences of a large-scale transition of solar PV energy in Greece during the debt crisis, as dictated by the country's national and European energy commitments by 2020. In the following section, we elaborate on the methodology used and the effect of the crisis on our final results from a more general point of view. Additionally, some final comments on the conclusions of the thesis are presented.

Concerning the performed analysis, our SCBA calculations were conducted in two parts, depending on the group with standing: the financial part from the private investors' perspective, and the socio-economic part from the whole Greek society's perspective. In the first analysis only the market prices were considered, in contrast to the second one where shadow prices and opportunity costs were taken into account along with all the possible social externalities that influence society's welfare. The different costs and benefits considered in each CBA made a substantial difference on the final results, with the socio-economic part yielding much more gains in all scenarios examined. Responsible for the social CBA's superiority are in fact its higher aggregated revenues. To be more precise, in the financial part revenues resulted mainly from selling the produced solar energy to consumers, while in the social part they were a sum of the Greek people's WTP for RES and the savings deriving from decreased lignite consumption, less natural gas and crude oil imports and reduced environmental pollution.

Focusing on the Greek debt crisis, its adverse consequences were evident in most of the inputs of our SCBA calculations, especially the ones used for the financial part. The annual income tax rate of 26%, the revised and more conservative FIT system, the total abolition of subsidies for PV power plants, the high inflation rate, the small amounts of loans granted from the Greek banks with high interest rates as well as the low discount rate considered in our financial calculations, were all factors influenced by the crisis in a negative way. The effect of the crisis was also confirmed by the small difference observed between the calculated IRR values and the private investor's rate of return in the financial CBA; the estimated former ranged between 4.13% - 6.97% while the latter was 3.14%.

Despite the crisis, our SCBA findings pointed out that the realization of the proposed case-study would benefit not only private investors but also the Greek society as a whole, offering the Greek economy a chance to emerge from recession. However, this certainty is not enough to put in motion the realization of such a plan, as the prevailing conditions in the country are not favorable at the time being. The Greek State strives to find funding by receiving loans from its creditors in order to fulfill basic obligations towards its citizens, such as salaries and pensions. The European Union expects further state reforms with the implementation of more austerity measures. The public institutions handling energy issues are working inefficiently with bureaucracy causing serious delays. The private investors are not attracted to invest on energy projects in such an unstable economic environment without the motivation of supporting incentives. Last but not least, the Greek people's awareness and acceptance of RES projects is still low. In order to overcome this standstill and initiate RES investments a series of policy reforms could be implemented, as described in detail in sub-chapter 7.2.

In conclusion, we shouldn't forget that Greece has a rich solar potential which, if exploited wisely, can contribute to the recovery of the Greek economy from the debt crisis. However, the Greek State should not remain confined to the implementation of similar RES projects. To ensure not only the economic recovery but also the future growth of the country, Greece should work on alternative solutions towards this direction. One short-term recommendation would be to introduce more pioneering projects, like the project "HELIOS", which was supposed to take advantage of the Greek solar potential by producing energy and then export it to countries of Northern Europe. Another suggestion would be the initiation and support of a domestic solar PV industry. Even though, the deployment of a robust PV industry would require a lot of time and effort to become competitive, in the long-run it would bring benefits, contributing to the decrease of PV system imports from abroad. Last but not least, Greece could use PV technology to create its own niche market. By employing its academic workforce in the research and development of the 3rd generation of photovoltaics for either domestic or industrial use, Greek scientists could bring PV technology one step further. Certainly, the introduction and development of a "new" technology demands certain supportive policies and regulations that reduce risks and create incentives for investors and entrepreneurs to promote it. Yet, the creation of a new niche market, where Greece would be the pioneer, could secure the country's economic prosperity in the future.

7.4.4 Personal Reflections

As a final conclusion, I would like to refer to my personal reflections on the current thesis. The conduction of this report was very challenging, since it required the combination of knowledge and information deriving from various scientific fields. However, thanks to this extensive research, I was able to raise my awareness on multiple topics. First of all, I understood in depth the dynamics of a financial crisis and its negative influence on a country's welfare. Furthermore, I gathered interesting information on the current energy status of Greece and its national targets till 2020, as imposed by the country itself and the European Commission. The explanation of the solar PV technology that followed reminded me of the operating principals of photovoltaics systems, from small systems to large scale power plants. Of course, the most important knowledge acquired was my acquaintance with the method of SCBA and the ability to apply it in order to evaluate the contribution of my case-study to the improvement of the Greek crisis. Through this learning process, I understood the big necessity of a reliable decision-making tool that can be used by national authorities for the assessment of new projects and policies. After the conduction of the current thesis, I would definitely recommend the SCBA as one.

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Appendix A

Table 30: Analytical Calculations for the Private Cost Benefit Analysis of the Project.

Baseline Scenario : NPV=48,523,344.936 € / Real IRR=5.42 %

Years (t)	Own Capital (Cown,t)	O&M Costs (OCt)	Revenues (Rt)	Depreciation Expenses (Dt)	Interest Payments (It)	Revenues after taxes (Rt-Oct- Dt-It-Tt)	Principal Payments (Pt)	Net Cash Flow (NCFt)	Salvage Value SV	NCFt+SVt-Cown,t
2016	32,760,000.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	-32,760,000.00 €
2017	32,760,000.00 €	1,092,000.00 €	5,328,842.90 €	2,730,000.00 €	1,004,640.00 €	371,630.15 €	1,769,060.88 €	1,332,569.27 €	0.00 €	-31,427,430.73 €
2018	32,760,000.00 €	2,184,000.00 €	11,068,367.31 €	5,460,000.00 €	1,927,903.20 €	1,107,383.44 €	3,619,498.56 €	2,947,884.88 €	0.00 €	-29,812,115.12 €
2019	33,588,000.00 €	3,276,000.00 €	17,058,307.27 €	8,190,000.00 €	2,766,046.27 €	2,091,433.14 €	5,555,056.38 €	4,726,376.76 €	0.00 €	-28,861,623.24 €
2020	34,488,000.00 €	4,395,600.00 €	23,048,247.22 €	10,989,000.00 €	3,540,545.67 €	3,051,095.15 €	7,624,362.38 €	6,415,732.77 €	0.00 €	-28,072,267.23 €
2021	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	4,247,457.00 €	3,983,072.33 €	9,837,457.03 €	8,008,615.30 €	0.00 €	8,008,615.30 €
2022	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	3,794,933.98 €	4,317,939.37 €	10,289,980.06 €	7,890,959.31 €	0.00 €	7,890,959.31 €
2023	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	3,321,594.90 €	4,668,210.29 €	10,763,319.14 €	7,767,891.15 €	0.00 €	7,767,891.15 €
2024	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	2,826,482.22 €	5,034,593.67 €	11,258,431.82 €	7,639,161.85 €	0.00 €	7,639,161.85 €
2025	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	2,308,594.35 €	5,417,830.69 €	11,776,319.68 €	7,504,511.01 €	0.00 €	7,504,511.01 €
2026	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,766,883.65 €	5,818,696.61 €	12,318,030.39 €	7,363,666.22 €	0.00 €	7,363,666.22 €
2027	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,200,254.25 €	6,238,002.37 €	10,110,958.91 €	9,990,043.46 €	0.00 €	9,990,043.46 €
2028	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	735,150.14 €	6,582,179.41 €	7,802,362.13 €	12,642,817.27 €	0.00 €	12,642,817.27 €
2029	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	376,241.48 €	6,847,771.82 €	5,387,569.91 €	15,323,201.90 €	0.00 €	15,323,201.90 €
2030	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	128,413.27 €	7,031,164.70 €	2,791,592.72 €	18,102,571.98 €	0.00 €	18,102,571.98 €
2031	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2032	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2033	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2034	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2035	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2036	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	8,190,000.00 €	29,179,190.51 €
2037	0.00 €	4,453,200.00 €	23,709,344.27 €	11,133,000.00 €	0.00 €	6,011,126.76 €	0.00 €	17,144,126.76 €	8,190,000.00 €	25,334,126.76 €
2038	0.00 €	3,361,200.00 €	17,969,819.87 €	8,403,000.00 €	0.00 €	4,592,158.70 €	0.00 €	12,995,158.70 €	8,190,000.00 €	21,185,158.70 €
2039	0.00 €	2,269,200.00 €	11,979,879.91 €	5,673,000.00 €	0.00 €	2,987,883.13 €	0.00 €	8,660,883.13 €	8,397,000.00 €	17,057,883.13 €
2040	0.00 €	1,149,600.00 €	5,989,939.96 €	2,874,000.00 €	0.00 €	1,455,091.57 €	0.00 €	4,329,091.57 €	8,622,000.00 €	12,951,091.57 €

Minimum Capacity Factor Scenario : NPV=26,100,970.413 € / Real IRR=4.38 %

Years (t)	Own Capital (Cown,t)	O&M Costs (OCt)	Revenues (Rt)	Depreciation Expenses (Dt)	Interest Payments (It)	Revenues after taxes (Rt-Oct- Dt-It-Tt)	Principal Payments (Pt)	Net Cash Flow (NCFt)	Salvage Value SV	NCFt+SVt-Cown,t
2016	32,760,000.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	-32,760,000.00 €
2017	32,760,000.00 €	1,092,000.00 €	5,091,305.87 €	2,730,000.00 €	1,004,640.00 €	195,852.74 €	1,769,060.88 €	1,156,791.86 €	0.00 €	-31,603,208.14 €
2018	32,760,000.00 €	2,184,000.00 €	10,417,286.88 €	5,460,000.00 €	1,927,903.20 €	625,583.92 €	3,619,498.56 €	2,466,085.36 €	0.00 €	-30,293,914.64 €
2019	33,588,000.00 €	3,276,000.00 €	15,886,362.49 €	8,190,000.00 €	2,766,046.27 €	1,224,194.01 €	5,555,056.38 €	3,859,137.63 €	0.00 €	-29,728,862.37 €
2020	34,488,000.00 €	4,395,600.00 €	21,355,438.10 €	10,989,000.00 €	3,540,545.67 €	1,798,416.40 €	7,624,362.38 €	5,163,054.02 €	0.00 €	-29,324,945.98 €
2021	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	4,247,457.00 €	2,344,953.97 €	9,837,457.03 €	6,370,496.93 €	0.00 €	6,370,496.93 €
2022	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	3,794,933.98 €	2,679,821.01 €	10,289,980.06 €	6,252,840.95 €	0.00 €	6,252,840.95 €
2023	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	3,321,594.90 €	3,030,091.93 €	10,763,319.14 €	6,129,772.79 €	0.00 €	6,129,772.79 €
2024	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	2,826,482.22 €	3,396,475.31 €	11,258,431.82 €	6,001,043.49 €	0.00 €	6,001,043.49 €
2025	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	2,308,594.35 €	3,779,712.33 €	11,776,319.68 €	5,866,392.65 €	0.00 €	5,866,392.65 €
2026	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	1,766,883.65 €	4,180,578.25 €	12,318,030.39 €	5,725,547.86 €	0.00 €	5,725,547.86 €
2027	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	1,200,254.25 €	4,599,884.01 €	10,110,958.91 €	8,351,925.10 €	0.00 €	8,351,925.10 €
2028	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	735,150.14 €	4,944,061.05 €	7,802,362.13 €	11,004,698.91 €	0.00 €	11,004,698.91 €
2029	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	376,241.48 €	5,209,653.45 €	5,387,569.91 €	13,685,083.54 €	0.00 €	13,685,083.54 €
2030	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	128,413.27 €	5,393,046.33 €	2,791,592.72 €	16,464,453.62 €	0.00 €	16,464,453.62 €
2031	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	0.00 €	5,488,072.15 €	0.00 €	19,351,072.15 €	0.00 €	19,351,072.15 €
2032	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	0.00 €	5,488,072.15 €	0.00 €	19,351,072.15 €	0.00 €	19,351,072.15 €
2033	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	0.00 €	5,488,072.15 €	0.00 €	19,351,072.15 €	0.00 €	19,351,072.15 €
2034	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	0.00 €	5,488,072.15 €	0.00 €	19,351,072.15 €	0.00 €	19,351,072.15 €
2035	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	0.00 €	5,488,072.15 €	0.00 €	19,351,072.15 €	0.00 €	19,351,072.15 €
2036	0.00 €	5,545,200.00 €	26,824,513.72 €	13,863,000.00 €	0.00 €	5,488,072.15 €	0.00 €	19,351,072.15 €	8,190,000.00 €	27,541,072.15 €
2037	0.00 €	4,453,200.00 €	21,733,207.85 €	11,133,000.00 €	0.00 €	4,548,785.81 €	0.00 €	15,681,785.81 €	8,190,000.00 €	23,871,785.81 €
2038	0.00 €	3,361,200.00 €	16,407,226.84 €	8,403,000.00 €	0.00 €	3,435,839.86 €	0.00 €	11,838,839.86 €	8,190,000.00 €	20,028,839.86 €
2039	0.00 €	2,269,200.00 €	10,938,151.22 €	5,673,000.00 €	0.00 €	2,217,003.91 €	0.00 €	7,890,003.91 €	8,397,000.00 €	16,287,003.91 €
2040	0.00 €	1,149,600.00 €	5,469,075.61 €	2,874,000.00 €	0.00 €	1,069,651.95 €	0.00 €	3,943,651.95 €	8,622,000.00 €	12,565,651.95 €

Maximum Capacity Factor Scenario : NPV=70,945,719.459 € / Real IRR=6.43 %										
Years (t)	Own Capital (Cown,t)	O&M Costs (OCt)	Revenues (Rt)	Depreciation Expenses (Dt)	Interest Payments (It)	Revenues after taxes (Rt-Oct- Dt-It-Tt)	Principal Payments (Pt)	Net Cash Flow (NCFt)	Salvage Value SV	NCFt+SVt-Cown,t
2016	32,760,000.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	-32,760,000.00 €
2017	32,760,000.00 €	1,092,000.00 €	5,566,379.94 €	2,730,000.00 €	1,004,640.00 €	547,407.56 €	1,769,060.88 €	1,508,346.67 €	0.00 €	-31,251,653.33 €
2018	32,760,000.00 €	2,184,000.00 €	11,719,447.74 €	5,460,000.00 €	1,927,903.20 €	1,589,182.96 €	3,619,498.56 €	3,429,684.40 €	0.00 €	-29,330,315.60 €
2019	33,588,000.00 €	3,276,000.00 €	18,230,252.04 €	8,190,000.00 €	2,766,046.27 €	2,958,672.27 €	5,555,056.38 €	5,593,615.89 €	0.00 €	-27,994,384.11 €
2020	34,488,000.00 €	4,395,600.00 €	24,741,056.34 €	10,989,000.00 €	3,540,545.67 €	4,303,773.89 €	7,624,362.38 €	7,668,411.51 €	0.00 €	-26,819,588.49 €
2021	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	4,247,457.00 €	5,621,190.69 €	9,837,457.03 €	9,646,733.66 €	0.00 €	9,646,733.66 €
2022	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	3,794,933.98 €	5,956,057.73 €	10,289,980.06 €	9,529,077.67 €	0.00 €	9,529,077.67 €
2023	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	3,321,594.90 €	6,306,328.65 €	10,763,319.14 €	9,406,009.51 €	0.00 €	9,406,009.51 €
2024	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	2,826,482.22 €	6,672,712.03 €	11,258,431.82 €	9,277,280.21 €	0.00 €	9,277,280.21 €
2025	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	2,308,594.35 €	7,055,949.05 €	11,776,319.68 €	9,142,629.37 €	0.00 €	9,142,629.37 €
2026	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	1,766,883.65 €	7,456,814.98 €	12,318,030.39 €	9,001,784.59 €	0.00 €	9,001,784.59 €
2027	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	1,200,254.25 €	7,876,120.73 €	10,110,958.91 €	11,628,161.82 €	0.00 €	11,628,161.82 €
2028	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	735,150.14 €	8,220,297.77 €	7,802,362.13 €	14,280,935.64 €	0.00 €	14,280,935.64 €
2029	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	376,241.48 €	8,485,890.18 €	5,387,569.91 €	16,961,320.27 €	0.00 €	16,961,320.27 €
2030	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	128,413.27 €	8,669,283.06 €	2,791,592.72 €	19,740,690.34 €	0.00 €	19,740,690.34 €
2031	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	0.00 €	8,764,308.87 €	0.00 €	22,627,308.87 €	0.00 €	22,627,308.87 €
2032	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	0.00 €	8,764,308.87 €	0.00 €	22,627,308.87 €	0.00 €	22,627,308.87 €
2033	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	0.00 €	8,764,308.87 €	0.00 €	22,627,308.87 €	0.00 €	22,627,308.87 €
2034	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	0.00 €	8,764,308.87 €	0.00 €	22,627,308.87 €	0.00 €	22,627,308.87 €
2035	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	0.00 €	8,764,308.87 €	0.00 €	22,627,308.87 €	0.00 €	22,627,308.87 €
2036	0.00 €	5,545,200.00 €	31,251,860.64 €	13,863,000.00 €	0.00 €	8,764,308.87 €	0.00 €	22,627,308.87 €	8,190,000.00 €	30,817,308.87 €
2037	0.00 €	4,453,200.00 €	25,685,480.70 €	11,133,000.00 €	0.00 €	7,473,467.72 €	0.00 €	18,606,467.72 €	8,190,000.00 €	26,796,467.72 €
2038	0.00 €	3,361,200.00 €	19,532,412.90 €	8,403,000.00 €	0.00 €	5,748,477.55 €	0.00 €	14,151,477.55 €	8,190,000.00 €	22,341,477.55 €
2039	0.00 €	2,269,200.00 €	13,021,608.60 €	5,673,000.00 €	0.00 €	3,758,762.36 €	0.00 €	9,431,762.36 €	8,397,000.00 €	17,828,762.36 €
2040	0.00 €	1,149,600.00 €	6,510,804.30 €	2,874,000.00 €	0.00 €	1,840,531.18 €	0.00 €	4,714,531.18 €	8,622,000.00 €	13,336,531.18 €

Minimum Investment Costs Scenario : NPV=74,159,920.350 € / Real IRR=6.97 %										
Years (t)	Own Capital (Cown,t)	O&M Costs (OCt)	Revenues (Rt)	Depreciation Expenses (Dt)	Interest Payments (It)	Revenues after taxes (Rt-Oct- Dt-It-Tt)	Principal Payments (Pt)	Net Cash Flow (NCFt)	Salvage Value SV	NCFt+SVt-Cown,t
2016	29,484,000.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	-29,484,000.00 €
2017	29,484,000.00 €	982,800.00 €	5,328,842.90 €	2,457,000.00 €	904,176.00 €	728,801.51 €	1,592,154.79 €	1,593,646.72 €	0.00 €	-27,890,353.28 €
2018	29,484,000.00 €	1,965,600.00 €	11,068,367.31 €	4,914,000.00 €	1,735,112.88 €	1,815,704.28 €	3,257,548.71 €	3,472,155.57 €	0.00 €	-26,011,844.43 €
2019	30,036,000.00 €	2,948,400.00 €	17,058,307.27 €	7,371,000.00 €	2,489,441.64 €	3,144,604.56 €	4,999,550.74 €	5,516,053.82 €	0.00 €	-24,519,946.18 €
2020	30,636,000.00 €	3,949,600.00 €	23,048,247.22 €	9,874,000.00 €	3,180,566.30 €	4,472,619.88 €	6,851,493.22 €	7,495,126.66 €	0.00 €	-23,140,873.34 €
2021	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	3,804,901.62 €	5,798,259.32 €	8,821,025.44 €	9,404,233.88 €	0.00 €	9,404,233.88 €
2022	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	3,399,134.45 €	6,098,527.02 €	9,226,792.61 €	9,298,734.42 €	0.00 €	9,298,734.42 €
2023	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	2,974,701.99 €	6,412,607.04 €	9,651,225.07 €	9,188,381.98 €	0.00 €	9,188,381.98 €
2024	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	2,530,745.63 €	6,741,134.74 €	10,095,181.42 €	9,072,953.32 €	0.00 €	9,072,953.32 €
2025	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	2,066,367.29 €	7,084,774.72 €	10,559,559.76 €	8,952,214.95 €	0.00 €	8,952,214.95 €
2026	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	1,580,627.54 €	7,444,222.13 €	11,045,299.51 €	8,825,922.62 €	0.00 €	8,825,922.62 €
2027	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	1,072,543.76 €	7,820,204.13 €	9,057,052.50 €	11,190,151.63 €	0.00 €	11,190,151.63 €
2028	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	655,919.35 €	8,128,506.19 €	6,977,346.12 €	13,578,160.08 €	0.00 €	13,578,160.08 €
2029	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	334,961.43 €	8,366,015.06 €	4,801,973.25 €	15,991,041.81 €	0.00 €	15,991,041.81 €
2030	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	114,070.66 €	8,529,474.23 €	2,479,796.87 €	18,476,677.35 €	0.00 €	18,476,677.35 €
2031	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	0.00 €	8,613,886.51 €	0.00 €	21,040,886.51 €	0.00 €	21,040,886.51 €
2032	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	0.00 €	8,613,886.51 €	0.00 €	21,040,886.51 €	0.00 €	21,040,886.51 €
2033	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	0.00 €	8,613,886.51 €	0.00 €	21,040,886.51 €	0.00 €	21,040,886.51 €
2034	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	0.00 €	8,613,886.51 €	0.00 €	21,040,886.51 €	0.00 €	21,040,886.51 €
2035	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	0.00 €	8,613,886.51 €	0.00 €	21,040,886.51 €	0.00 €	21,040,886.51 €
2036	0.00 €	4,970,800.00 €	29,038,187.18 €	12,427,000.00 €	0.00 €	8,613,886.51 €	0.00 €	21,040,886.51 €	7,371,000.00 €	28,411,886.51 €
2037	0.00 €	3,988,000.00 €	23,709,344.27 €	9,970,000.00 €	0.00 €	7,215,994.76 €	0.00 €	17,185,994.76 €	7,371,000.00 €	24,556,994.76 €
2038	0.00 €	3,005,200.00 €	17,969,819.87 €	7,513,000.00 €	0.00 €	5,514,198.70 €	0.00 €	13,027,198.70 €	7,371,000.00 €	20,398,198.70 €
2039	0.00 €	2,022,400.00 €	11,979,879.91 €	5,056,000.00 €	0.00 €	3,627,095.13 €	0.00 €	8,683,095.13 €	7,509,000.00 €	16,192,095.13 €
2040	0.00 €	1,021,200.00 €	5,989,939.96 €	2,553,000.00 €	0.00 €	1,787,647.57 €	0.00 €	4,340,647.57 €	7,659,000.00 €	11,999,647.57 €

Maximum Investment Costs Scenario : NPV=22,886,769.522 € / Real IRR=4.13 %										
Years (t)	Own Capital (Cown,t)	O&M Costs (OCt)	Revenues (Rt)	Depreciation Expenses (Dt)	Interest Payments (It)	Revenues after taxes (Rt-Oct- Dt-It-Tt)	Principal Payments (Pt)	Net Cash Flow (NCFt)	Salvage Value SV	NCFt+SVt-Cown,t
2016	36,036,000.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	-36,036,000.00 €
2017	36,036,000.00 €	1,201,200.00 €	5,328,842.90 €	3,003,000.00 €	1,105,104.00 €	14,458.79 €	1,945,966.97 €	1,071,491.82 €	0.00 €	-34,964,508.18 €
2018	36,036,000.00 €	2,402,400.00 €	11,068,367.31 €	6,006,000.00 €	2,120,693.52 €	399,062.61 €	3,981,448.42 €	2,423,614.19 €	0.00 €	-33,612,385.81 €
2019	37,140,000.00 €	3,603,600.00 €	17,058,307.27 €	9,009,000.00 €	3,042,650.89 €	1,038,261.72 €	6,110,562.02 €	3,936,699.70 €	0.00 €	-33,203,300.30 €
2020	38,340,000.00 €	4,841,600.00 €	23,048,247.22 €	12,104,000.00 €	3,900,525.04 €	1,629,570.42 €	8,397,231.54 €	5,336,338.87 €	0.00 €	-33,003,661.13 €
2021	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	4,690,012.39 €	2,167,885.34 €	10,853,888.63 €	6,612,996.71 €	0.00 €	6,612,996.71 €
2022	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	4,190,733.51 €	2,537,351.71 €	11,353,167.51 €	6,483,184.20 €	0.00 €	6,483,184.20 €
2023	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	3,668,487.81 €	2,923,813.54 €	11,875,413.21 €	6,347,400.32 €	0.00 €	6,347,400.32 €
2024	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	3,122,218.80 €	3,328,052.60 €	12,421,682.22 €	6,205,370.38 €	0.00 €	6,205,370.38 €
2025	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	2,550,821.42 €	3,750,886.66 €	12,993,079.60 €	6,056,807.06 €	0.00 €	6,056,807.06 €
2026	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	1,953,139.75 €	4,193,171.09 €	13,590,761.27 €	5,901,409.83 €	0.00 €	5,901,409.83 €
2027	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	1,327,964.74 €	4,655,800.61 €	11,164,865.31 €	8,789,935.29 €	0.00 €	8,789,935.29 €
2028	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	814,380.93 €	5,035,852.62 €	8,627,378.15 €	11,707,474.47 €	0.00 €	11,707,474.47 €
2029	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	417,521.54 €	5,329,528.57 €	5,973,166.58 €	14,655,362.00 €	0.00 €	14,655,362.00 €
2030	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	142,755.87 €	5,532,855.16 €	3,103,388.56 €	17,728,466.60 €	0.00 €	17,728,466.60 €
2031	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	0.00 €	5,638,494.51 €	0.00 €	20,937,494.51 €	0.00 €	20,937,494.51 €
2032	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	0.00 €	5,638,494.51 €	0.00 €	20,937,494.51 €	0.00 €	20,937,494.51 €
2033	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	0.00 €	5,638,494.51 €	0.00 €	20,937,494.51 €	0.00 €	20,937,494.51 €
2034	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	0.00 €	5,638,494.51 €	0.00 €	20,937,494.51 €	0.00 €	20,937,494.51 €
2035	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	0.00 €	5,638,494.51 €	0.00 €	20,937,494.51 €	0.00 €	20,937,494.51 €
2036	0.00 €	6,119,600.00 €	29,038,187.18 €	15,299,000.00 €	0.00 €	5,638,494.51 €	0.00 €	20,937,494.51 €	9,009,000.00 €	29,946,494.51 €
2037	0.00 €	4,918,400.00 €	23,709,344.27 €	12,296,000.00 €	0.00 €	4,806,258.76 €	0.00 €	17,102,258.76 €	9,009,000.00 €	26,111,258.76 €
2038	0.00 €	3,717,200.00 €	17,969,819.87 €	9,293,000.00 €	0.00 €	3,670,118.70 €	0.00 €	12,963,118.70 €	9,009,000.00 €	21,972,118.70 €
2039	0.00 €	2,516,000.00 €	11,979,879.91 €	6,290,000.00 €	0.00 €	2,348,671.13 €	0.00 €	8,638,671.13 €	9,285,000.00 €	17,923,671.13 €
2040	0.00 €	1,278,000.00 €	5,989,939.96 €	3,195,000.00 €	0.00 €	1,122,535.57 €	0.00 €	4,317,535.57 €	9,585,000.00 €	13,902,535.57 €

Minimum Share of Loan Scenario : NPV=49,236,468.451 € / Real IRR=5.17 %										
Years (t)	Own Capital (Cown,t)	O&M Costs (OCt)	Revenues (Rt)	Depreciation Expenses (Dt)	Interest Payments (It)	Revenues after taxes (Rt-Oct- Dt-It-Tt)	Principal Payments (Pt)	Net Cash Flow (NCFt)	Salvage Value SV	NCFt+SVt-Cown,t
2016	43,680,000.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	-43,680,000.00 €
2017	43,680,000.00 €	1,092,000.00 €	5,328,842.90 €	2,730,000.00 €	502,320.00 €	743,346.95 €	884,530.44 €	2,588,816.51 €	0.00 €	-41,091,183.49 €
2018	43,680,000.00 €	2,184,000.00 €	11,068,367.31 €	5,460,000.00 €	963,951.60 €	1,820,707.63 €	1,809,749.28 €	5,470,958.34 €	0.00 €	-38,209,041.66 €
2019	44,784,000.00 €	3,276,000.00 €	17,058,307.27 €	8,190,000.00 €	1,383,023.13 €	3,114,870.26 €	2,777,528.19 €	8,527,342.07 €	0.00 €	-36,256,657.93 €
2020	45,984,000.00 €	4,395,600.00 €	23,048,247.22 €	10,989,000.00 €	1,770,272.84 €	4,361,097.05 €	3,812,181.19 €	11,537,915.85 €	0.00 €	-34,446,084.15 €
2021	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	2,123,728.50 €	5,554,631.42 €	4,918,728.52 €	14,498,902.90 €	0.00 €	14,498,902.90 €
2022	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,897,466.99 €	5,722,064.94 €	5,144,990.03 €	14,440,074.91 €	0.00 €	14,440,074.91 €
2023	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,660,797.45 €	5,897,200.40 €	5,381,659.57 €	14,378,540.83 €	0.00 €	14,378,540.83 €
2024	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,413,241.11 €	6,080,392.09 €	5,629,215.91 €	14,314,176.18 €	0.00 €	14,314,176.18 €
2025	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,154,297.18 €	6,272,010.60 €	5,888,159.84 €	14,246,850.76 €	0.00 €	14,246,850.76 €
2026	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	883,441.82 €	6,472,443.56 €	6,159,015.19 €	14,176,428.37 €	0.00 €	14,176,428.37 €
2027	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	600,127.12 €	6,682,096.44 €	5,055,479.45 €	15,489,616.99 €	0.00 €	15,489,616.99 €
2028	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	367,575.07 €	6,854,184.96 €	3,901,181.07 €	16,816,003.89 €	0.00 €	16,816,003.89 €
2029	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	188,120.74 €	6,986,981.16 €	2,693,784.96 €	18,156,196.21 €	0.00 €	18,156,196.21 €
2030	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	64,206.63 €	7,078,677.60 €	1,395,796.36 €	19,545,881.24 €	0.00 €	19,545,881.24 €
2031	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2032	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2033	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2034	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2035	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2036	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	8,190,000.00 €	29,179,190.51 €
2037	0.00 €	4,453,200.00 €	23,709,344.27 €	11,133,000.00 €	0.00 €	6,011,126.76 €	0.00 €	17,144,126.76 €	8,190,000.00 €	25,334,126.76 €
2038	0.00 €	3,361,200.00 €	17,969,819.87 €	8,403,000.00 €	0.00 €	4,592,158.70 €	0.00 €	12,995,158.70 €	8,190,000.00 €	21,185,158.70 €
2039	0.00 €	2,269,200.00 €	11,979,879.91 €	5,673,000.00 €	0.00 €	2,987,883.13 €	0.00 €	8,660,883.13 €	8,397,000.00 €	17,057,883.13 €
2040	0.00 €	1,149,600.00 €	5,989,939.96 €	2,874,000.00 €	0.00 €	1,455,091.57 €	0.00 €	4,329,091.57 €	8,622,000.00 €	12,951,091.57 €

Maximum Share of Loan Scenario : NPV=47,810,221.422 € / Real IRR=5.75 %										
Years (t)	Own Capital (Cown,t)	O&M Costs (OCt)	Revenues (Rt)	Depreciation Expenses (Dt)	Interest Payments (It)	Revenues after taxes (Rt-Oct- Dt-It-Tt)	Principal Payments (Pt)	Net Cash Flow (NCFt)	Salvage Value SV	NCFt+SVt-Cown,t
2016	21,840,000.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	-21,840,000.00 €
2017	21,840,000.00 €	1,092,000.00 €	5,328,842.90 €	2,730,000.00 €	1,506,960.00 €	-86.65 €	2,653,591.32 €	76,322.03 €	0.00 €	-21,763,677.97 €
2018	21,840,000.00 €	2,184,000.00 €	11,068,367.31 €	5,460,000.00 €	2,891,854.80 €	394,059.26 €	5,429,247.85 €	424,811.41 €	0.00 €	-21,415,188.59 €
2019	22,392,000.00 €	3,276,000.00 €	17,058,307.27 €	8,190,000.00 €	4,149,069.40 €	1,067,996.02 €	8,332,584.57 €	925,411.45 €	0.00 €	-21,466,588.55 €
2020	22,992,000.00 €	4,395,600.00 €	23,048,247.22 €	10,989,000.00 €	5,310,818.51 €	1,741,093.25 €	11,436,543.57 €	1,293,549.68 €	0.00 €	-21,698,450.32 €
2021	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	6,371,185.50 €	2,411,513.24 €	14,756,185.55 €	1,518,327.69 €	0.00 €	1,518,327.69 €
2022	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	5,692,400.97 €	2,913,813.80 €	15,434,970.09 €	1,341,843.71 €	0.00 €	1,341,843.71 €
2023	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	4,982,392.34 €	3,439,220.18 €	16,144,978.71 €	1,157,241.47 €	0.00 €	1,157,241.47 €
2024	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	4,239,723.32 €	3,988,795.25 €	16,887,647.73 €	964,147.52 €	0.00 €	964,147.52 €
2025	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	3,462,891.53 €	4,563,650.78 €	17,664,479.53 €	762,171.25 €	0.00 €	762,171.25 €
2026	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	2,650,325.47 €	5,164,949.66 €	18,477,045.58 €	550,904.08 €	0.00 €	550,904.08 €
2027	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,800,381.37 €	5,793,908.30 €	15,166,438.36 €	4,490,469.94 €	0.00 €	4,490,469.94 €
2028	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,102,725.21 €	6,310,173.86 €	11,703,543.20 €	8,469,630.66 €	0.00 €	8,469,630.66 €
2029	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	564,362.22 €	6,708,562.47 €	8,081,354.87 €	12,490,207.60 €	0.00 €	12,490,207.60 €
2030	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	192,619.90 €	6,983,651.79 €	4,187,389.08 €	16,659,262.71 €	0.00 €	16,659,262.71 €
2031	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2032	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2033	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2034	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2035	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2036	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	8,190,000.00 €	29,179,190.51 €
2037	0.00 €	4,453,200.00 €	23,709,344.27 €	11,133,000.00 €	0.00 €	6,011,126.76 €	0.00 €	17,144,126.76 €	8,190,000.00 €	25,334,126.76 €
2038	0.00 €	3,361,200.00 €	17,969,819.87 €	8,403,000.00 €	0.00 €	4,592,158.70 €	0.00 €	12,995,158.70 €	8,190,000.00 €	21,185,158.70 €
2039	0.00 €	2,269,200.00 €	11,979,879.91 €	5,673,000.00 €	0.00 €	2,987,883.13 €	0.00 €	8,660,883.13 €	8,397,000.00 €	17,057,883.13 €
2040	0.00 €	1,149,600.00 €	5,989,939.96 €	2,874,000.00 €	0.00 €	1,455,091.57 €	0.00 €	4,329,091.57 €	8,622,000.00 €	12,951,091.57 €

Minimum Real Ineterest Rate Scenario : NPV=52,488,803.797 € / Real IRR=5.62 %										
Years (t)	Own Capital (Cown,t)	O&M Costs (OCt)	Revenues (Rt)	Depreciation Expenses (Dt)	Interest Payments (It)	Revenues after taxes (Rt-Oct- Dt-It-Tt)	Principal Payments (Pt)	Net Cash Flow (NCFt)	Salvage Value SV	NCFt+SVt-Cown,t
2016	32,760,000.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	-32,760,000.00 €
2017	32,760,000.00 €	1,092,000.00 €	5,328,842.90 €	2,730,000.00 €	786,240.00 €	533,246.15 €	1,853,084.67 €	1,410,161.48 €	0.00 €	-31,349,838.52 €
2018	32,760,000.00 €	2,184,000.00 €	11,068,367.31 €	5,460,000.00 €	1,505,768.95 €	1,419,762.78 €	3,772,880.38 €	3,106,882.40 €	0.00 €	-29,653,117.60 €
2019	33,588,000.00 €	3,276,000.00 €	17,058,307.27 €	8,190,000.00 €	2,156,185.26 €	2,542,730.29 €	5,761,788.74 €	4,970,941.54 €	0.00 €	-28,617,058.46 €
2020	34,488,000.00 €	4,395,600.00 €	23,048,247.22 €	10,989,000.00 €	2,754,872.86 €	3,632,493.03 €	7,869,134.01 €	6,752,359.02 €	0.00 €	-27,735,640.98 €
2021	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	3,299,296.04 €	4,684,711.44 €	10,103,252.63 €	8,444,458.82 €	0.00 €	8,444,458.82 €
2022	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	2,935,578.94 €	4,953,862.09 €	10,466,969.72 €	8,349,892.37 €	0.00 €	8,349,892.37 €
2023	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	2,558,768.03 €	5,232,702.17 €	10,843,780.63 €	8,251,921.53 €	0.00 €	8,251,921.53 €
2024	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	2,168,391.93 €	5,521,580.48 €	11,234,156.73 €	8,150,423.75 €	0.00 €	8,150,423.75 €
2025	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,763,962.29 €	5,820,858.42 €	11,638,586.38 €	8,045,272.04 €	0.00 €	8,045,272.04 €
2026	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,344,973.18 €	6,130,910.36 €	12,057,575.49 €	7,936,334.87 €	0.00 €	7,936,334.87 €
2027	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	910,900.46 €	6,452,124.17 €	9,852,323.54 €	10,462,800.63 €	0.00 €	10,462,800.63 €
2028	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	556,216.82 €	6,714,590.07 €	7,567,682.52 €	13,009,907.55 €	0.00 €	13,009,907.55 €
2029	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	283,780.24 €	6,916,193.13 €	5,200,794.42 €	15,578,398.71 €	0.00 €	15,578,398.71 €
2030	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	96,551.65 €	7,054,742.29 €	2,681,990.15 €	18,235,752.15 €	0.00 €	18,235,752.15 €
2031	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2032	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2033	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2034	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2035	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2036	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	8,190,000.00 €	29,179,190.51 €
2037	0.00 €	4,453,200.00 €	23,709,344.27 €	11,133,000.00 €	0.00 €	6,011,126.76 €	0.00 €	17,144,126.76 €	8,190,000.00 €	25,334,126.76 €
2038	0.00 €	3,361,200.00 €	17,969,819.87 €	8,403,000.00 €	0.00 €	4,592,158.70 €	0.00 €	12,995,158.70 €	8,190,000.00 €	21,185,158.70 €
2039	0.00 €	2,269,200.00 €	11,979,879.91 €	5,673,000.00 €	0.00 €	2,987,883.13 €	0.00 €	8,660,883.13 €	8,397,000.00 €	17,057,883.13 €
2040	0.00 €	1,149,600.00 €	5,989,939.96 €	2,874,000.00 €	0.00 €	1,455,091.57 €	0.00 €	4,329,091.57 €	8,622,000.00 €	12,951,091.57 €

Maximum Real Ineterest Rate Scenario : NPV=44,458,291.244 € / Real IRR=5.22 %										
Years (t)	Own Capital (Cown,t)	O&M Costs (OCt)	Revenues (Rt)	Depreciation Expenses (Dt)	Interest Payments (It)	Revenues after taxes (Rt-Oct- Dt-It-Tt)	Principal Payments (Pt)	Net Cash Flow (NCFt)	Salvage Value SV	NCFt+SVt-Cown,t
2016	32,760,000.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	-32,760,000.00 €
2017	32,760,000.00 €	1,092,000.00 €	5,328,842.90 €	2,730,000.00 €	1,223,040.00 €	210,014.15 €	1,688,338.17 €	1,251,675.98 €	0.00 €	-31,508,324.02 €
2018	32,760,000.00 €	2,184,000.00 €	11,068,367.31 €	5,460,000.00 €	2,351,533.06 €	793,897.34 €	3,471,223.28 €	2,782,674.06 €	0.00 €	-29,977,325.94 €
2019	33,588,000.00 €	3,276,000.00 €	17,058,307.27 €	8,190,000.00 €	3,380,184.56 €	1,636,970.80 €	5,353,949.96 €	4,473,020.85 €	0.00 €	-29,114,979.15 €
2020	34,488,000.00 €	4,395,600.00 €	23,048,247.22 €	10,989,000.00 €	4,334,315.36 €	2,463,705.58 €	7,384,781.61 €	6,067,923.97 €	0.00 €	-28,420,076.03 €
2021	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	5,208,319.59 €	3,272,034.01 €	9,575,722.75 €	7,559,311.26 €	0.00 €	7,559,311.26 €
2022	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	4,672,079.12 €	3,668,851.97 €	10,111,963.22 €	7,419,888.74 €	0.00 €	7,419,888.74 €
2023	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	4,105,809.18 €	4,087,891.72 €	10,678,233.16 €	7,272,658.56 €	0.00 €	7,272,658.56 €
2024	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	3,507,828.12 €	4,530,397.70 €	11,276,214.22 €	7,117,183.48 €	0.00 €	7,117,183.48 €
2025	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	2,876,360.12 €	4,997,684.02 €	11,907,682.22 €	6,953,001.80 €	0.00 €	6,953,001.80 €
2026	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	2,209,529.92 €	5,491,138.37 €	12,574,512.42 €	6,779,625.95 €	0.00 €	6,779,625.95 €
2027	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,505,357.22 €	6,012,226.17 €	10,367,306.95 €	9,507,919.22 €	0.00 €	9,507,919.22 €
2028	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	924,788.03 €	6,441,847.37 €	8,036,497.96 €	12,268,349.40 €	0.00 €	12,268,349.40 €
2029	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	474,744.15 €	6,774,879.84 €	5,575,163.68 €	15,062,716.16 €	0.00 €	15,062,716.16 €
2030	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	162,534.98 €	7,005,914.63 €	2,902,410.39 €	17,966,504.24 €	0.00 €	17,966,504.24 €
2031	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2032	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2033	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2034	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2035	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2036	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	8,190,000.00 €	29,179,190.51 €
2037	0.00 €	4,453,200.00 €	23,709,344.27 €	11,133,000.00 €	0.00 €	6,011,126.76 €	0.00 €	17,144,126.76 €	8,190,000.00 €	25,334,126.76 €
2038	0.00 €	3,361,200.00 €	17,969,819.87 €	8,403,000.00 €	0.00 €	4,592,158.70 €	0.00 €	12,995,158.70 €	8,190,000.00 €	21,185,158.70 €
2039	0.00 €	2,269,200.00 €	11,979,879.91 €	5,673,000.00 €	0.00 €	2,987,883.13 €	0.00 €	8,660,883.13 €	8,397,000.00 €	17,057,883.13 €
2040	0.00 €	1,149,600.00 €	5,989,939.96 €	2,874,000.00 €	0.00 €	1,455,091.57 €	0.00 €	4,329,091.57 €	8,622,000.00 €	12,951,091.57 €

Minimum Real Discount Rate Scenario : NPV=77,461,503.822 € / Real IRR=5.42 %										
Years (t)	Own Capital (Cown,t)	O&M Costs (OCt)	Revenues (Rt)	Depreciation Expenses (Dt)	Interest Payments (It)	Revenues after taxes (Rt-Oct- Dt-It-Tt)	Principal Payments (Pt)	Net Cash Flow (NCFt)	Salvage Value SV	NCFt+SVt-Cown,t
2016	32,760,000.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	-32,760,000.00 €
2017	32,760,000.00 €	1,092,000.00 €	5,328,842.90 €	2,730,000.00 €	1,004,640.00 €	371,630.15 €	1,769,060.88 €	1,332,569.27 €	0.00 €	-31,427,430.73 €
2018	32,760,000.00 €	2,184,000.00 €	11,068,367.31 €	5,460,000.00 €	1,927,903.20 €	1,107,383.44 €	3,619,498.56 €	2,947,884.88 €	0.00 €	-29,812,115.12 €
2019	33,588,000.00 €	3,276,000.00 €	17,058,307.27 €	8,190,000.00 €	2,766,046.27 €	2,091,433.14 €	5,555,056.38 €	4,726,376.76 €	0.00 €	-28,861,623.24 €
2020	34,488,000.00 €	4,395,600.00 €	23,048,247.22 €	10,989,000.00 €	3,540,545.67 €	3,051,095.15 €	7,624,362.38 €	6,415,732.77 €	0.00 €	-28,072,267.23 €
2021	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	4,247,457.00 €	3,983,072.33 €	9,837,457.03 €	8,008,615.30 €	0.00 €	8,008,615.30 €
2022	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	3,794,933.98 €	4,317,939.37 €	10,289,980.06 €	7,890,959.31 €	0.00 €	7,890,959.31 €
2023	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	3,321,594.90 €	4,668,210.29 €	10,763,319.14 €	7,767,891.15 €	0.00 €	7,767,891.15 €
2024	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	2,826,482.22 €	5,034,593.67 €	11,258,431.82 €	7,639,161.85 €	0.00 €	7,639,161.85 €
2025	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	2,308,594.35 €	5,417,830.69 €	11,776,319.68 €	7,504,511.01 €	0.00 €	7,504,511.01 €
2026	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,766,883.65 €	5,818,696.61 €	12,318,030.39 €	7,363,666.22 €	0.00 €	7,363,666.22 €
2027	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,200,254.25 €	6,238,002.37 €	10,110,958.91 €	9,990,043.46 €	0.00 €	9,990,043.46 €
2028	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	735,150.14 €	6,582,179.41 €	7,802,362.13 €	12,642,817.27 €	0.00 €	12,642,817.27 €
2029	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	376,241.48 €	6,847,771.82 €	5,387,569.91 €	15,323,201.90 €	0.00 €	15,323,201.90 €
2030	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	128,413.27 €	7,031,164.70 €	2,791,592.72 €	18,102,571.98 €	0.00 €	18,102,571.98 €
2031	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2032	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2033	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2034	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2035	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2036	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	8,190,000.00 €	29,179,190.51 €
2037	0.00 €	4,453,200.00 €	23,709,344.27 €	11,133,000.00 €	0.00 €	6,011,126.76 €	0.00 €	17,144,126.76 €	8,190,000.00 €	25,334,126.76 €
2038	0.00 €	3,361,200.00 €	17,969,819.87 €	8,403,000.00 €	0.00 €	4,592,158.70 €	0.00 €	12,995,158.70 €	8,190,000.00 €	21,185,158.70 €
2039	0.00 €	2,269,200.00 €	11,979,879.91 €	5,673,000.00 €	0.00 €	2,987,883.13 €	0.00 €	8,660,883.13 €	8,397,000.00 €	17,057,883.13 €
2040	0.00 €	1,149,600.00 €	5,989,939.96 €	2,874,000.00 €	0.00 €	1,455,091.57 €	0.00 €	4,329,091.57 €	8,622,000.00 €	12,951,091.57 €

Maximum Real Discount Rate Scenario : NPV=24,625,472.024 € / Real IRR=5.42 %

Years (t)	Own Capital (Cown,t)	O&M Costs (OCt)	Revenues (Rt)	Depreciation Expenses (Dt)	Interest Payments (It)	Revenues after taxes (Rt-Oct- Dt-It-Tt)	Principal Payments (Pt)	Net Cash Flow (NCFt)	Salvage Value SV	NCFt+SVt-Cown,t
2016	32,760,000.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	-32,760,000.00 €
2017	32,760,000.00 €	1,092,000.00 €	5,328,842.90 €	2,730,000.00 €	1,004,640.00 €	371,630.15 €	1,769,060.88 €	1,332,569.27 €	0.00 €	-31,427,430.73 €
2018	32,760,000.00 €	2,184,000.00 €	11,068,367.31 €	5,460,000.00 €	1,927,903.20 €	1,107,383.44 €	3,619,498.56 €	2,947,884.88 €	0.00 €	-29,812,115.12 €
2019	33,588,000.00 €	3,276,000.00 €	17,058,307.27 €	8,190,000.00 €	2,766,046.27 €	2,091,433.14 €	5,555,056.38 €	4,726,376.76 €	0.00 €	-28,861,623.24 €
2020	34,488,000.00 €	4,395,600.00 €	23,048,247.22 €	10,989,000.00 €	3,540,545.67 €	3,051,095.15 €	7,624,362.38 €	6,415,732.77 €	0.00 €	-28,072,267.23 €
2021	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	4,247,457.00 €	3,983,072.33 €	9,837,457.03 €	8,008,615.30 €	0.00 €	8,008,615.30 €
2022	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	3,794,933.98 €	4,317,939.37 €	10,289,980.06 €	7,890,959.31 €	0.00 €	7,890,959.31 €
2023	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	3,321,594.90 €	4,668,210.29 €	10,763,319.14 €	7,767,891.15 €	0.00 €	7,767,891.15 €
2024	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	2,826,482.22 €	5,034,593.67 €	11,258,431.82 €	7,639,161.85 €	0.00 €	7,639,161.85 €
2025	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	2,308,594.35 €	5,417,830.69 €	11,776,319.68 €	7,504,511.01 €	0.00 €	7,504,511.01 €
2026	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,766,883.65 €	5,818,696.61 €	12,318,030.39 €	7,363,666.22 €	0.00 €	7,363,666.22 €
2027	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	1,200,254.25 €	6,238,002.37 €	10,110,958.91 €	9,990,043.46 €	0.00 €	9,990,043.46 €
2028	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	735,150.14 €	6,582,179.41 €	7,802,362.13 €	12,642,817.27 €	0.00 €	12,642,817.27 €
2029	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	376,241.48 €	6,847,771.82 €	5,387,569.91 €	15,323,201.90 €	0.00 €	15,323,201.90 €
2030	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	128,413.27 €	7,031,164.70 €	2,791,592.72 €	18,102,571.98 €	0.00 €	18,102,571.98 €
2031	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2032	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2033	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2034	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2035	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	0.00 €	20,989,190.51 €
2036	0.00 €	5,545,200.00 €	29,038,187.18 €	13,863,000.00 €	0.00 €	7,126,190.51 €	0.00 €	20,989,190.51 €	8,190,000.00 €	29,179,190.51 €
2037	0.00 €	4,453,200.00 €	23,709,344.27 €	11,133,000.00 €	0.00 €	6,011,126.76 €	0.00 €	17,144,126.76 €	8,190,000.00 €	25,334,126.76 €
2038	0.00 €	3,361,200.00 €	17,969,819.87 €	8,403,000.00 €	0.00 €	4,592,158.70 €	0.00 €	12,995,158.70 €	8,190,000.00 €	21,185,158.70 €
2039	0.00 €	2,269,200.00 €	11,979,879.91 €	5,673,000.00 €	0.00 €	2,987,883.13 €	0.00 €	8,660,883.13 €	8,397,000.00 €	17,057,883.13 €
2040	0.00 €	1,149,600.00 €	5,989,939.96 €	2,874,000.00 €	0.00 €	1,455,091.57 €	0.00 €	4,329,091.57 €	8,622,000.00 €	12,951,091.57 €

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Appendix B

Table 31: Analytical Calculations for the Socio-Economic Cost Benefit Analysis of the Project.

Baseline Scenario : SNPV=190,301,404.13 € / Real SRR=13.62%								
Years	Investment Cost	Total O&M Costs	Total Revenues	Salvage Value	Total External Costs	Total External Benefits	Net Social Benefits (NSB)	Present Value of NSB
2016	€ 51,886,800.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	-€ 51,886,800.00	-€ 51,886,800.00
2017	€ 51,198,000.00	€ 1,086,540.00	€ 13,925,048.00	€ 0.00	€ 630,567.27	€ 5,173,981.88	-€ 33,816,077.38	-€ 32,205,787.98
2018	€ 50,778,000.00	€ 2,173,080.00	€ 13,925,048.00	€ 0.00	€ 1,306,562.20	€ 10,720,710.58	-€ 29,611,883.62	-€ 26,858,851.35
2019	€ 51,929,840.00	€ 3,259,620.00	€ 13,925,048.00	€ 0.00	€ 2,008,776.17	€ 16,482,573.87	-€ 26,790,614.30	-€ 23,142,739.92
2020	€ 53,181,840.00	€ 4,373,622.00	€ 13,925,048.00	€ 0.00	€ 2,707,428.36	€ 22,666,757.86	-€ 23,671,084.50	-€ 19,474,259.80
2021	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,402,518.76	€ 29,310,258.37	€ 34,315,313.61	€ 26,886,946.12
2022	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,385,251.84	€ 29,161,573.87	€ 34,183,896.03	€ 25,508,549.54
2023	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,367,984.92	€ 29,012,889.38	€ 34,052,478.46	€ 24,200,460.69
2024	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,350,717.99	€ 28,864,204.88	€ 33,921,060.89	€ 22,959,109.21
2025	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,333,451.07	€ 28,715,520.39	€ 33,789,643.32	€ 21,781,105.36
2026	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,316,184.15	€ 28,566,835.89	€ 33,658,225.74	€ 20,663,230.87
2027	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,298,917.23	€ 28,418,151.40	€ 33,526,808.17	€ 19,602,430.37
2028	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,281,650.31	€ 28,269,466.91	€ 33,395,390.60	€ 18,595,803.08
2029	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,264,383.38	€ 28,120,782.41	€ 33,263,973.03	€ 17,640,595.10
2030	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,247,116.46	€ 27,972,097.92	€ 33,132,555.45	€ 16,734,191.96
2031	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,229,849.54	€ 27,823,413.42	€ 33,001,137.88	€ 15,874,111.58
2032	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,212,582.62	€ 27,674,728.93	€ 32,869,720.31	€ 15,057,997.60
2033	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,195,315.70	€ 27,526,044.43	€ 32,738,302.74	€ 14,283,613.04
2034	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,178,048.77	€ 27,377,359.94	€ 32,606,885.16	€ 13,548,834.28
2035	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,160,781.85	€ 27,228,675.44	€ 32,475,467.59	€ 12,851,645.30
2036	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 7,783,020.00	€ 3,143,514.93	€ 27,079,990.95	€ 40,127,070.02	€ 15,123,470.67
2037	€ 0.00	€ 4,430,934.00	€ 13,925,048.00	€ 7,679,700.00	€ 2,559,054.34	€ 22,277,322.75	€ 36,892,082.41	€ 13,242,131.30
2038	€ 0.00	€ 3,344,394.00	€ 13,925,048.00	€ 7,616,700.00	€ 1,934,050.13	€ 17,141,982.78	€ 33,405,286.65	€ 11,419,592.93
2039	€ 0.00	€ 2,257,854.00	€ 13,925,048.00	€ 7,789,476.00	€ 1,285,804.97	€ 11,815,944.23	€ 29,986,809.27	€ 9,762,844.65
2040	€ 0.00	€ 1,143,852.00	€ 13,925,048.00	€ 7,977,276.00	€ 641,121.59	€ 6,112,966.50	€ 26,230,316.91	€ 8,133,179.55

Minimum Capacity Factor Scenario : SNPV=168,862,631.49 € / Real SRR=12.72%								
Years	Investment Cost	Total O&M Costs	Total Revenues	Salvage Value	Total External Costs	Total External Benefits	Net Social Benefits	Present Value of NSB
2016	€ 51,886,800.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	-€ 51,886,800.00	-€ 51,886,800.00
2017	€ 51,198,000.00	€ 1,086,540.00	€ 13,925,048.00	€ 0.00	€ 602,459.27	€ 4,943,347.89	-€ 34,018,603.38	-€ 32,398,669.89
2018	€ 50,778,000.00	€ 2,173,080.00	€ 13,925,048.00	€ 0.00	€ 1,229,660.45	€ 10,089,710.11	-€ 30,165,982.35	-€ 27,361,435.23
2019	€ 51,929,840.00	€ 3,259,620.00	€ 13,925,048.00	€ 0.00	€ 1,870,627.18	€ 15,349,022.52	-€ 27,786,016.66	-€ 24,002,605.91
2020	€ 53,181,840.00	€ 4,373,622.00	€ 13,925,048.00	€ 0.00	€ 2,508,341.85	€ 20,993,932.10	-€ 25,144,823.75	-€ 20,686,708.72
2021	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,142,804.44	€ 27,058,217.63	€ 32,322,987.19	€ 25,325,906.24
2022	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,126,853.84	€ 26,920,942.94	€ 32,201,663.10	€ 24,029,376.81
2023	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,110,903.23	€ 26,783,668.25	€ 32,080,339.02	€ 22,798,898.01
2024	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,094,952.62	€ 26,646,393.56	€ 31,959,014.94	€ 21,631,119.29
2025	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,079,002.01	€ 26,509,118.87	€ 31,837,690.86	€ 20,522,859.40
2026	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,063,051.40	€ 26,371,844.18	€ 31,716,366.78	€ 19,471,097.92
2027	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,047,100.79	€ 26,234,569.49	€ 31,595,042.70	€ 18,472,967.11
2028	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,031,150.18	€ 26,097,294.80	€ 31,473,718.62	€ 17,525,744.22
2029	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,015,199.57	€ 25,960,020.11	€ 31,352,394.54	€ 16,626,844.22
2030	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 2,999,248.96	€ 25,822,745.42	€ 31,231,070.46	€ 15,773,812.83
2031	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 2,983,298.35	€ 25,685,470.73	€ 31,109,746.38	€ 14,964,319.93
2032	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 2,967,347.74	€ 25,548,196.04	€ 30,988,422.30	€ 14,196,153.30
2033	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 2,951,397.13	€ 25,410,921.35	€ 30,867,098.22	€ 13,467,212.71
2034	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 2,935,446.52	€ 25,273,646.66	€ 30,745,774.14	€ 12,775,504.20
2035	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 2,919,495.91	€ 25,136,371.97	€ 30,624,450.06	€ 12,119,134.80
2036	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 7,783,020.00	€ 2,903,545.30	€ 24,999,097.28	€ 38,286,145.98	€ 14,429,645.76
2037	€ 0.00	€ 4,430,934.00	€ 13,925,048.00	€ 7,679,700.00	€ 2,345,684.09	€ 20,415,293.58	€ 35,243,423.49	€ 12,650,357.77
2038	€ 0.00	€ 3,344,394.00	€ 13,925,048.00	€ 7,616,700.00	€ 1,765,871.86	€ 15,651,375.58	€ 32,082,857.72	€ 10,967,520.78
2039	€ 0.00	€ 2,257,854.00	€ 13,925,048.00	€ 7,789,476.00	€ 1,173,995.84	€ 10,788,470.82	€ 29,071,144.98	€ 9,464,730.63
2040	€ 0.00	€ 1,143,852.00	€ 13,925,048.00	€ 7,977,276.00	€ 585,371.89	€ 5,581,404.20	€ 25,754,504.31	€ 7,985,645.33

Maximum Capacity Factor Scenario : SNPV=211,740,176.78 € / Real SRR=14.50%								
Years	Investment Cost	Total O&M Costs	Total Revenues	Salvage Value	Total External Costs	Total External Benefits	Net Social Benefits	Present Value of NSB
2016	€ 51,886,800.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	-€ 51,886,800.00	-€ 51,886,800.00
2017	€ 51,198,000.00	€ 1,086,540.00	€ 13,925,048.00	€ 0.00	€ 658,675.26	€ 5,404,615.88	-€ 33,613,551.38	-€ 32,012,906.08
2018	€ 50,778,000.00	€ 2,173,080.00	€ 13,925,048.00	€ 0.00	€ 1,383,463.95	€ 11,351,711.06	-€ 29,057,784.89	-€ 26,356,267.47
2019	€ 51,929,840.00	€ 3,259,620.00	€ 13,925,048.00	€ 0.00	€ 2,146,925.16	€ 17,616,125.22	-€ 25,795,211.95	-€ 22,282,873.94
2020	€ 53,181,840.00	€ 4,373,622.00	€ 13,925,048.00	€ 0.00	€ 2,906,514.87	€ 24,339,583.62	-€ 22,197,345.25	-€ 18,261,810.87
2021	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,662,233.08	€ 31,562,299.11	€ 36,307,640.03	€ 28,447,986.01
2022	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,643,649.84	€ 31,402,204.81	€ 36,166,128.96	€ 26,987,722.27
2023	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,625,066.61	€ 31,242,110.51	€ 36,024,617.90	€ 25,602,023.37
2024	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,606,483.37	€ 31,082,016.21	€ 35,883,106.84	€ 24,287,099.14
2025	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,587,900.14	€ 30,921,921.91	€ 35,741,595.77	€ 23,039,351.31
2026	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,569,316.90	€ 30,761,827.61	€ 35,600,084.71	€ 21,855,363.83
2027	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,550,733.67	€ 30,601,733.31	€ 35,458,573.64	€ 20,731,893.63
2028	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,532,150.44	€ 30,441,639.01	€ 35,317,062.58	€ 19,665,861.94
2029	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,513,567.20	€ 30,281,544.71	€ 35,175,551.51	€ 18,654,345.99
2030	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,494,983.97	€ 30,121,450.41	€ 35,034,040.45	€ 17,694,571.09
2031	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,476,400.73	€ 29,961,356.11	€ 34,892,529.38	€ 16,783,903.23
2032	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,457,817.50	€ 29,801,261.82	€ 34,751,018.32	€ 15,919,841.89
2033	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,439,234.26	€ 29,641,167.52	€ 34,609,507.25	€ 15,100,013.37
2034	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,420,651.03	€ 29,481,073.22	€ 34,467,996.19	€ 14,322,164.35
2035	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,402,067.79	€ 29,320,978.92	€ 34,326,485.12	€ 13,584,155.79
2036	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 7,783,020.00	€ 3,383,484.56	€ 29,160,884.62	€ 41,967,994.06	€ 15,817,295.58
2037	€ 0.00	€ 4,430,934.00	€ 13,925,048.00	€ 7,679,700.00	€ 2,772,424.58	€ 24,139,351.92	€ 38,540,741.33	€ 13,833,904.83
2038	€ 0.00	€ 3,344,394.00	€ 13,925,048.00	€ 7,616,700.00	€ 2,102,228.40	€ 18,632,589.98	€ 34,727,715.58	€ 11,871,665.09
2039	€ 0.00	€ 2,257,854.00	€ 13,925,048.00	€ 7,789,476.00	€ 1,397,614.09	€ 12,843,417.64	€ 30,902,473.55	€ 10,060,958.67
2040	€ 0.00	€ 1,143,852.00	€ 13,925,048.00	€ 7,977,276.00	€ 696,871.29	€ 6,644,528.81	€ 26,706,129.51	€ 8,280,713.77

Minimum Investment Costs Scenario : SNPV=219,664,500.84 € / Real SRR=15.98%								
Years	Investment Cost	Total O&M Costs	Total Revenues	Salvage Value	Total External Costs	Total External Benefits	Net Social Benefits	Present Value of NSB
2016	€ 46,698,120.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	-€ 46,698,120.00	-€ 46,698,120.00
2017	€ 46,078,200.00	€ 977,886.00	€ 13,925,048.00	€ 0.00	€ 630,567.27	€ 5,173,981.88	-€ 28,587,623.38	-€ 27,226,307.98
2018	€ 45,700,200.00	€ 1,955,772.00	€ 13,925,048.00	€ 0.00	€ 1,306,562.20	€ 10,720,710.58	-€ 24,316,775.62	-€ 22,056,032.30
2019	€ 46,444,480.00	€ 2,933,658.00	€ 13,925,048.00	€ 0.00	€ 2,008,776.17	€ 16,482,573.87	-€ 20,979,292.30	-€ 18,122,701.48
2020	€ 47,253,480.00	€ 3,929,852.00	€ 13,925,048.00	€ 0.00	€ 2,707,428.36	€ 22,666,757.86	-€ 17,298,954.50	-€ 14,231,892.68
2021	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,402,518.76	€ 29,310,258.37	€ 34,886,841.61	€ 27,334,753.26
2022	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,385,251.84	€ 29,161,573.87	€ 34,755,424.03	€ 25,935,032.53
2023	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,367,984.92	€ 29,012,889.38	€ 34,624,006.46	€ 24,606,634.97
2024	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,350,717.99	€ 28,864,204.88	€ 34,492,588.89	€ 23,345,941.86
2025	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,333,451.07	€ 28,715,520.39	€ 34,361,171.32	€ 22,149,517.40
2026	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,316,184.15	€ 28,566,835.89	€ 34,229,753.74	€ 21,014,099.49
2027	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,298,917.23	€ 28,418,151.40	€ 34,098,336.17	€ 19,936,590.95
2028	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,281,650.31	€ 28,269,466.91	€ 33,966,918.60	€ 18,914,051.26
2029	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,264,383.38	€ 28,120,782.41	€ 33,835,501.03	€ 17,943,688.60
2030	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,247,116.46	€ 27,972,097.92	€ 33,704,083.45	€ 17,022,852.44
2031	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,229,849.54	€ 27,823,413.42	€ 33,572,665.88	€ 16,149,026.32
2032	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,212,582.62	€ 27,674,728.93	€ 33,441,248.31	€ 15,319,821.16
2033	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,195,315.70	€ 27,526,044.43	€ 33,309,830.74	€ 14,532,968.81
2034	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,178,048.77	€ 27,377,359.94	€ 33,178,413.16	€ 13,786,315.96
2035	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 0.00	€ 3,160,781.85	€ 27,228,675.44	€ 33,046,995.59	€ 13,077,818.33
2036	€ 0.00	€ 4,945,946.00	€ 13,925,048.00	€ 7,004,718.00	€ 3,143,514.93	€ 27,079,990.95	€ 39,920,296.02	€ 15,045,539.72
2037	€ 0.00	€ 3,968,060.00	€ 13,925,048.00	€ 6,911,730.00	€ 2,559,054.34	€ 22,277,322.75	€ 36,586,986.41	€ 13,132,619.42
2038	€ 0.00	€ 2,990,174.00	€ 13,925,048.00	€ 6,855,030.00	€ 1,934,050.13	€ 17,141,982.78	€ 32,997,836.65	€ 11,280,306.20
2039	€ 0.00	€ 2,012,288.00	€ 13,925,048.00	€ 6,966,672.00	€ 1,285,804.97	€ 11,815,944.23	€ 29,409,571.27	€ 9,574,912.52
2040	€ 0.00	€ 1,016,094.00	€ 13,925,048.00	€ 7,088,022.00	€ 641,121.59	€ 6,112,966.50	€ 25,468,820.91	€ 7,897,064.08

Maximum Investment Costs Scenario : SNPV=160,938,307.42 € / Real SRR=11.68%								
Years	Investment Cost	Total O&M Costs	Total Revenues	Salvage Value	Total External Costs	Total External Benefits	Net Social Benefits	Present Value of NSB
2016	€ 57,075,480.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	-€ 57,075,480.00	-€ 57,075,480.00
2017	€ 56,317,800.00	€ 1,195,194.00	€ 13,925,048.00	€ 0.00	€ 630,567.27	€ 5,173,981.88	-€ 39,044,531.38	-€ 37,185,267.98
2018	€ 55,855,800.00	€ 2,390,388.00	€ 13,925,048.00	€ 0.00	€ 1,306,562.20	€ 10,720,710.58	-€ 34,906,991.62	-€ 31,661,670.40
2019	€ 57,415,200.00	€ 3,585,582.00	€ 13,925,048.00	€ 0.00	€ 2,008,776.17	€ 16,482,573.87	-€ 32,601,936.30	-€ 28,162,778.36
2020	€ 59,110,200.00	€ 4,817,392.00	€ 13,925,048.00	€ 0.00	€ 2,707,428.36	€ 22,666,757.86	-€ 30,043,214.50	-€ 24,716,626.92
2021	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,402,518.76	€ 29,310,258.37	€ 33,743,785.61	€ 26,439,138.98
2022	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,385,251.84	€ 29,161,573.87	€ 33,612,368.03	€ 25,082,066.54
2023	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,367,984.92	€ 29,012,889.38	€ 33,480,950.46	€ 23,794,286.41
2024	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,350,717.99	€ 28,864,204.88	€ 33,349,532.89	€ 22,572,276.56
2025	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,333,451.07	€ 28,715,520.39	€ 33,218,115.32	€ 21,412,693.31
2026	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,316,184.15	€ 28,566,835.89	€ 33,086,697.74	€ 20,312,362.26
2027	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,298,917.23	€ 28,418,151.40	€ 32,955,280.17	€ 19,268,269.78
2028	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,281,650.31	€ 28,269,466.91	€ 32,823,862.60	€ 18,277,554.90
2029	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,264,383.38	€ 28,120,782.41	€ 32,692,445.03	€ 17,337,501.60
2030	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,247,116.46	€ 27,972,097.92	€ 32,561,027.45	€ 16,445,531.48
2031	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,229,849.54	€ 27,823,413.42	€ 32,429,609.88	€ 15,599,196.84
2032	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,212,582.62	€ 27,674,728.93	€ 32,298,192.31	€ 14,796,174.04
2033	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,195,315.70	€ 27,526,044.43	€ 32,166,774.74	€ 14,034,257.27
2034	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,178,048.77	€ 27,377,359.94	€ 32,035,357.16	€ 13,311,352.59
2035	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 0.00	€ 3,160,781.85	€ 27,228,675.44	€ 31,903,939.59	€ 12,625,472.26
2036	€ 0.00	€ 6,089,002.00	€ 13,925,048.00	€ 8,561,322.00	€ 3,143,514.93	€ 27,079,990.95	€ 40,333,844.02	€ 15,201,401.61
2037	€ 0.00	€ 4,893,808.00	€ 13,925,048.00	€ 8,447,670.00	€ 2,559,054.34	€ 22,277,322.75	€ 37,197,178.41	€ 13,351,643.18
2038	€ 0.00	€ 3,698,614.00	€ 13,925,048.00	€ 8,378,370.00	€ 1,934,050.13	€ 17,141,982.78	€ 33,812,736.65	€ 11,558,879.66
2039	€ 0.00	€ 2,503,420.00	€ 13,925,048.00	€ 8,612,280.00	€ 1,285,804.97	€ 11,815,944.23	€ 30,564,047.27	€ 9,950,776.78
2040	€ 0.00	€ 1,271,610.00	€ 13,925,048.00	€ 8,866,530.00	€ 641,121.59	€ 6,112,966.50	€ 26,991,812.91	€ 8,369,295.02

Minimum Labor Costs Scenario : SNPV=199,417,835.60 € / Real SRR=14.37%								
Years	Investment Cost	Total O&M Costs	Total Revenues	Salvage Value	Total External Costs	Total External Benefits	Net Social Benefits	Present Value of NSB
2016	€ 50,296,800.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	-€ 50,296,800.00	-€ 50,296,800.00
2017	€ 49,239,000.00	€ 1,083,264.00	€ 13,925,048.00	€ 0.00	€ 630,567.27	€ 5,173,981.88	-€ 31,853,801.38	-€ 30,336,953.70
2018	€ 48,594,000.00	€ 2,166,528.00	€ 13,925,048.00	€ 0.00	€ 1,306,562.20	€ 10,720,710.58	-€ 27,421,331.62	-€ 24,871,956.11
2019	€ 49,612,900.00	€ 3,249,792.00	€ 13,925,048.00	€ 0.00	€ 2,008,776.17	€ 16,482,573.87	-€ 24,463,846.30	-€ 21,132,790.24
2020	€ 50,720,400.00	€ 4,360,435.20	€ 13,925,048.00	€ 0.00	€ 2,707,428.36	€ 22,666,757.86	-€ 21,196,457.70	-€ 17,438,378.21
2021	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,402,518.76	€ 29,310,258.37	€ 34,331,949.21	€ 26,899,980.55
2022	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,385,251.84	€ 29,161,573.87	€ 34,200,531.63	€ 25,520,963.28
2023	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,367,984.92	€ 29,012,889.38	€ 34,069,114.06	€ 24,212,283.30
2024	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,350,717.99	€ 28,864,204.88	€ 33,937,696.49	€ 22,970,368.84
2025	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,333,451.07	€ 28,715,520.39	€ 33,806,278.92	€ 21,791,828.81
2026	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,316,184.15	€ 28,566,835.89	€ 33,674,861.34	€ 20,673,443.69
2027	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,298,917.23	€ 28,418,151.40	€ 33,543,443.77	€ 19,612,156.86
2028	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,281,650.31	€ 28,269,466.91	€ 33,412,026.20	€ 18,605,066.40
2029	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,264,383.38	€ 28,120,782.41	€ 33,280,608.63	€ 17,649,417.32
2030	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,247,116.46	€ 27,972,097.92	€ 33,149,191.05	€ 16,742,594.07
2031	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,229,849.54	€ 27,823,413.42	€ 33,017,773.48	€ 15,882,113.59
2032	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,212,582.62	€ 27,674,728.93	€ 32,886,355.91	€ 15,065,618.56
2033	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,195,315.70	€ 27,526,044.43	€ 32,754,938.34	€ 14,290,871.10
2034	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,178,048.77	€ 27,377,359.94	€ 32,623,520.76	€ 13,555,746.71
2035	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 0.00	€ 3,160,781.85	€ 27,228,675.44	€ 32,492,103.19	€ 12,858,228.57
2036	€ 0.00	€ 5,500,838.40	€ 13,925,048.00	€ 7,544,520.00	€ 3,143,514.93	€ 27,079,990.95	€ 39,905,205.62	€ 15,039,852.31
2037	€ 0.00	€ 4,417,574.40	€ 13,925,048.00	€ 7,385,850.00	€ 2,559,054.34	€ 22,277,322.75	€ 36,611,592.01	€ 13,141,451.41
2038	€ 0.00	€ 3,334,310.40	€ 13,925,048.00	€ 7,289,100.00	€ 1,934,050.13	€ 17,141,982.78	€ 33,087,770.25	€ 11,311,049.99
2039	€ 0.00	€ 2,251,046.40	€ 13,925,048.00	€ 7,441,935.00	€ 1,285,804.97	€ 11,815,944.23	€ 29,646,075.87	€ 9,651,911.63
2040	€ 0.00	€ 1,140,403.20	€ 13,925,048.00	€ 7,608,060.00	€ 641,121.59	€ 6,112,966.50	€ 25,864,549.71	€ 8,019,766.88

Maximum Labor Costs Scenario : SNPV=181,235,812.03 € / Real SRR=12.93%								
Years	Investment Cost	Total O&M Costs	Total Revenues	Salvage Value	Total External Costs	Total External Benefits	Net Social Benefits	Present Value of NSB
2016	€ 53,437,200.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	-€ 53,437,200.00	-€ 53,437,200.00
2017	€ 53,142,000.00	€ 1,089,816.00	€ 13,925,048.00	€ 0.00	€ 630,567.27	€ 5,173,981.88	-€ 35,763,353.38	-€ 34,060,336.55
2018	€ 52,962,000.00	€ 2,179,632.00	€ 13,925,048.00	€ 0.00	€ 1,306,562.20	€ 10,720,710.58	-€ 31,802,435.62	-€ 28,845,746.59
2019	€ 54,246,780.00	€ 3,269,448.00	€ 13,925,048.00	€ 0.00	€ 2,008,776.17	€ 16,482,573.87	-€ 29,117,382.30	-€ 25,152,689.61
2020	€ 55,643,280.00	€ 4,386,808.80	€ 13,925,048.00	€ 0.00	€ 2,707,428.36	€ 22,666,757.86	-€ 26,145,711.30	-€ 21,510,141.39
2021	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,402,518.76	€ 29,310,258.37	€ 34,298,678.01	€ 26,873,911.69
2022	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,385,251.84	€ 29,161,573.87	€ 34,167,260.43	€ 25,496,135.80
2023	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,367,984.92	€ 29,012,889.38	€ 34,035,842.86	€ 24,188,638.08
2024	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,350,717.99	€ 28,864,204.88	€ 33,904,425.29	€ 22,947,849.58
2025	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,333,451.07	€ 28,715,520.39	€ 33,773,007.72	€ 21,770,381.90
2026	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,316,184.15	€ 28,566,835.89	€ 33,641,590.14	€ 20,653,018.06
2027	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,298,917.23	€ 28,418,151.40	€ 33,510,172.57	€ 19,592,703.88
2028	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,281,650.31	€ 28,269,466.91	€ 33,378,755.00	€ 18,586,539.76
2029	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,264,383.38	€ 28,120,782.41	€ 33,247,337.43	€ 17,631,772.89
2030	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,247,116.46	€ 27,972,097.92	€ 33,115,919.85	€ 16,725,789.85
2031	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,229,849.54	€ 27,823,413.42	€ 32,984,502.28	€ 15,866,109.57
2032	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,212,582.62	€ 27,674,728.93	€ 32,853,084.71	€ 15,050,376.64
2033	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,195,315.70	€ 27,526,044.43	€ 32,721,667.14	€ 14,276,354.98
2034	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,178,048.77	€ 27,377,359.94	€ 32,590,249.56	€ 13,541,921.84
2035	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 0.00	€ 3,160,781.85	€ 27,228,675.44	€ 32,458,831.99	€ 12,845,062.02
2036	€ 0.00	€ 5,534,109.60	€ 13,925,048.00	€ 8,015,580.00	€ 3,143,514.93	€ 27,079,990.95	€ 40,342,994.42	€ 15,204,850.30
2037	€ 0.00	€ 4,444,293.60	€ 13,925,048.00	€ 7,971,300.00	€ 2,559,054.34	€ 22,277,322.75	€ 37,170,322.81	€ 13,342,003.56
2038	€ 0.00	€ 3,354,477.60	€ 13,925,048.00	€ 7,944,300.00	€ 1,934,050.13	€ 17,141,982.78	€ 33,722,803.05	€ 11,528,135.88
2039	€ 0.00	€ 2,264,661.60	€ 13,925,048.00	€ 8,137,017.00	€ 1,285,804.97	€ 11,815,944.23	€ 30,327,542.67	€ 9,873,777.67
2040	€ 0.00	€ 1,147,300.80	€ 13,925,048.00	€ 8,346,492.00	€ 641,121.59	€ 6,112,966.50	€ 26,596,084.11	€ 8,246,592.22

Minimum WTP Scenario : SNPV=177,988,655.28 € / Real SRR=13.06%								
Years	Investment Cost	Total O&M Costs	Total Revenues	Salvage Value	Total External Costs	Total External Benefits	Net Social Benefits	Present Value of NSB
2016	€ 51,886,800.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	-€ 51,886,800.00	-€ 51,886,800.00
2017	€ 51,198,000.00	€ 1,086,540.00	€ 13,032,732.00	€ 0.00	€ 630,567.27	€ 5,173,981.88	-€ 34,708,393.38	-€ 33,055,612.74
2018	€ 50,778,000.00	€ 2,173,080.00	€ 13,032,732.00	€ 0.00	€ 1,306,562.20	€ 10,720,710.58	-€ 30,504,199.62	-€ 27,668,208.27
2019	€ 51,929,840.00	€ 3,259,620.00	€ 13,032,732.00	€ 0.00	€ 2,008,776.17	€ 16,482,573.87	-€ 27,682,930.30	-€ 23,913,556.03
2020	€ 53,181,840.00	€ 4,373,622.00	€ 13,032,732.00	€ 0.00	€ 2,707,428.36	€ 22,666,757.86	-€ 24,563,400.50	-€ 20,208,370.38
2021	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,402,518.76	€ 29,310,258.37	€ 33,422,997.61	€ 26,187,793.19
2022	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,385,251.84	€ 29,161,573.87	€ 33,291,580.03	€ 24,842,689.60
2023	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,367,984.92	€ 29,012,889.38	€ 33,160,162.46	€ 23,566,308.37
2024	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,350,717.99	€ 28,864,204.88	€ 33,028,744.89	€ 22,355,154.62
2025	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,333,451.07	€ 28,715,520.39	€ 32,897,327.32	€ 21,205,910.51
2026	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,316,184.15	€ 28,566,835.89	€ 32,765,909.74	€ 20,115,426.26
2027	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,298,917.23	€ 28,418,151.40	€ 32,634,492.17	€ 19,080,711.68
2028	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,281,650.31	€ 28,269,466.91	€ 32,503,074.60	€ 18,098,928.14
2029	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,264,383.38	€ 28,120,782.41	€ 32,371,657.03	€ 17,167,380.88
2030	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,247,116.46	€ 27,972,097.92	€ 32,240,239.45	€ 16,283,511.74
2031	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,229,849.54	€ 27,823,413.42	€ 32,108,821.88	€ 15,444,892.32
2032	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,212,582.62	€ 27,674,728.93	€ 31,977,404.31	€ 14,649,217.36
2033	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,195,315.70	€ 27,526,044.43	€ 31,845,986.74	€ 13,894,298.53
2034	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,178,048.77	€ 27,377,359.94	€ 31,714,569.16	€ 13,178,058.55
2035	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 0.00	€ 3,160,781.85	€ 27,228,675.44	€ 31,583,151.59	€ 12,498,525.55
2036	€ 0.00	€ 5,517,474.00	€ 13,032,732.00	€ 7,783,020.00	€ 3,143,514.93	€ 27,079,990.95	€ 39,234,754.02	€ 14,787,166.15
2037	€ 0.00	€ 4,430,934.00	€ 13,032,732.00	€ 7,679,700.00	€ 2,559,054.34	€ 22,277,322.75	€ 35,999,766.41	€ 12,921,841.28
2038	€ 0.00	€ 3,344,394.00	€ 13,032,732.00	€ 7,616,700.00	€ 1,934,050.13	€ 17,141,982.78	€ 32,512,970.65	€ 11,114,554.83
2039	€ 0.00	€ 2,257,854.00	€ 13,032,732.00	€ 7,789,476.00	€ 1,285,804.97	€ 11,815,944.23	€ 29,094,493.27	€ 9,472,332.16
2040	€ 0.00	€ 1,143,852.00	€ 13,032,732.00	€ 7,977,276.00	€ 641,121.59	€ 6,112,966.50	€ 25,338,000.91	€ 7,856,500.99

Maximum WTP Scenario : SNPV=202,501,197.30 € / Real SRR=14.18%								
Years	Investment Cost	Total O&M Costs	Total Revenues	Salvage Value	Total External Costs	Total External Benefits	Net Social Benefits	Present Value of NSB
2016	€ 51,886,800.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	-€ 51,886,800.00	-€ 51,886,800.00
2017	€ 51,198,000.00	€ 1,086,540.00	€ 14,809,178.00	€ 0.00	€ 630,567.27	€ 5,173,981.88	-€ 32,931,947.38	-€ 31,363,759.41
2018	€ 50,778,000.00	€ 2,173,080.00	€ 14,809,178.00	€ 0.00	€ 1,306,562.20	€ 10,720,710.58	-€ 28,727,753.62	-€ 26,056,919.38
2019	€ 51,929,840.00	€ 3,259,620.00	€ 14,809,178.00	€ 0.00	€ 2,008,776.17	€ 16,482,573.87	-€ 25,906,484.30	-€ 22,378,995.19
2020	€ 53,181,840.00	€ 4,373,622.00	€ 14,809,178.00	€ 0.00	€ 2,707,428.36	€ 22,666,757.86	-€ 22,786,954.50	-€ 18,746,883.86
2021	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,402,518.76	€ 29,310,258.37	€ 35,199,443.61	€ 27,579,685.11
2022	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,385,251.84	€ 29,161,573.87	€ 35,068,026.03	€ 26,168,300.96
2023	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,367,984.92	€ 29,012,889.38	€ 34,936,608.46	€ 24,828,795.37
2024	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,350,717.99	€ 28,864,204.88	€ 34,805,190.89	€ 23,557,523.20
2025	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,333,451.07	€ 28,715,520.39	€ 34,673,773.32	€ 22,351,023.44
2026	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,316,184.15	€ 28,566,835.89	€ 34,542,355.74	€ 21,206,010.00
2027	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,298,917.23	€ 28,418,151.40	€ 34,410,938.17	€ 20,119,362.87
2028	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,281,650.31	€ 28,269,466.91	€ 34,279,520.60	€ 19,088,119.75
2029	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,264,383.38	€ 28,120,782.41	€ 34,148,103.03	€ 18,109,468.12
2030	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,247,116.46	€ 27,972,097.92	€ 34,016,685.45	€ 17,180,737.69
2031	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,229,849.54	€ 27,823,413.42	€ 33,885,267.88	€ 16,299,393.22
2032	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,212,582.62	€ 27,674,728.93	€ 33,753,850.31	€ 15,463,027.74
2033	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,195,315.70	€ 27,526,044.43	€ 33,622,432.74	€ 14,669,356.03
2034	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,178,048.77	€ 27,377,359.94	€ 33,491,015.16	€ 13,916,208.55
2035	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 0.00	€ 3,160,781.85	€ 27,228,675.44	€ 33,359,597.59	€ 13,201,525.56
2036	€ 0.00	€ 5,517,474.00	€ 14,809,178.00	€ 7,783,020.00	€ 3,143,514.93	€ 27,079,990.95	€ 41,011,200.02	€ 15,456,689.97
2037	€ 0.00	€ 4,430,934.00	€ 14,809,178.00	€ 7,679,700.00	€ 2,559,054.34	€ 22,277,322.75	€ 37,776,212.41	€ 13,559,483.01
2038	€ 0.00	€ 3,344,394.00	€ 14,809,178.00	€ 7,616,700.00	€ 1,934,050.13	€ 17,141,982.78	€ 34,289,416.65	€ 11,721,832.66
2039	€ 0.00	€ 2,257,854.00	€ 14,809,178.00	€ 7,789,476.00	€ 1,285,804.97	€ 11,815,944.23	€ 30,870,939.27	€ 10,050,692.01
2040	€ 0.00	€ 1,143,852.00	€ 14,809,178.00	€ 7,977,276.00	€ 641,121.59	€ 6,112,966.50	€ 27,114,446.91	€ 8,407,319.89

Minimum External Benefit IIb Scenario : SNPV=143,425,625.76 € / Real SRR=11.63%								
Years	Investment Cost	Total O&M Costs	Total Revenues	Salvage Value	Total External Costs	Total External Benefits	Net Social Benefits	Present Value of NSB
2016	€ 51,886,800.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	-€ 51,886,800.00	-€ 51,886,800.00
2017	€ 51,198,000.00	€ 1,086,540.00	€ 13,925,048.00	€ 0.00	€ 630,567.27	€ 4,499,156.60	-€ 34,490,902.67	-€ 32,848,478.73
2018	€ 50,778,000.00	€ 2,173,080.00	€ 13,925,048.00	€ 0.00	€ 1,306,562.20	€ 9,322,443.88	-€ 31,010,150.32	-€ 28,127,120.47
2019	€ 51,929,840.00	€ 3,259,620.00	€ 13,925,048.00	€ 0.00	€ 2,008,776.17	€ 14,332,806.46	-€ 28,940,381.72	-€ 24,999,789.84
2020	€ 53,181,840.00	€ 4,373,622.00	€ 13,925,048.00	€ 0.00	€ 2,707,428.36	€ 19,543,553.33	-€ 26,794,289.03	-€ 22,043,727.89
2021	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,402,518.76	€ 24,973,184.46	€ 29,978,239.70	€ 23,488,735.23
2022	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,385,251.84	€ 24,846,480.69	€ 29,868,802.85	€ 22,288,560.57
2023	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,367,984.92	€ 24,719,776.93	€ 29,759,366.01	€ 21,149,425.82
2024	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,350,717.99	€ 24,593,073.16	€ 29,649,929.17	€ 20,068,239.14
2025	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,333,451.07	€ 24,466,369.40	€ 29,540,492.33	€ 19,042,064.74
2026	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,316,184.15	€ 24,339,665.63	€ 29,431,055.48	€ 18,068,115.03
2027	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,298,917.23	€ 24,212,961.87	€ 29,321,618.64	€ 17,143,743.14
2028	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,281,650.31	€ 24,086,258.11	€ 29,212,181.80	€ 16,266,435.89
2029	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,264,383.38	€ 23,959,554.34	€ 29,102,744.96	€ 15,433,807.01
2030	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,247,116.46	€ 23,832,850.58	€ 28,993,308.11	€ 14,643,590.78
2031	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,229,849.54	€ 23,706,146.81	€ 28,883,871.27	€ 13,893,635.94
2032	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,212,582.62	€ 23,579,443.05	€ 28,774,434.43	€ 13,181,899.95
2033	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,195,315.70	€ 23,452,739.28	€ 28,664,997.59	€ 12,506,443.50
2034	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,178,048.77	€ 23,326,035.52	€ 28,555,560.74	€ 11,865,425.30
2035	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,160,781.85	€ 23,199,331.75	€ 28,446,123.90	€ 11,257,097.17
2036	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 7,783,020.00	€ 3,143,514.93	€ 23,072,627.99	€ 36,119,707.06	€ 13,613,137.71
2037	€ 0.00	€ 4,430,934.00	€ 13,925,048.00	€ 7,679,700.00	€ 2,559,054.34	€ 18,898,944.17	€ 33,513,703.83	€ 12,029,488.10
2038	€ 0.00	€ 3,344,394.00	€ 13,925,048.00	€ 7,616,700.00	€ 1,934,050.13	€ 14,435,977.86	€ 30,699,281.73	€ 10,494,545.50
2039	€ 0.00	€ 2,257,854.00	€ 13,925,048.00	€ 7,789,476.00	€ 1,285,804.97	€ 9,807,185.15	€ 27,978,050.18	€ 9,108,850.33
2040	€ 0.00	€ 1,143,852.00	€ 13,925,048.00	€ 7,977,276.00	€ 641,121.59	€ 5,000,701.40	€ 25,118,051.81	€ 7,788,301.83

Maximum External Benefit IIb Scenario : SNPV=202,254,221.50 € / Real SRR=14.07%								
Years	**Investment Cost**	**Total O&M Costs**	**Total Revenues**	**Salvage Value**	**Total External Costs**	**Total External Benefits**	**Net Social Benefits**	**Present Value of NSB**
2016	€ 51,886,800.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	-€ 51,886,800.00	-€ 51,886,800.00
2017	€ 51,198,000.00	€ 1,086,540.00	€ 13,925,048.00	€ 0.00	€ 630,567.27	€ 5,226,565.67	-€ 33,763,493.59	-€ 32,155,708.18
2018	€ 50,778,000.00	€ 2,173,080.00	€ 13,925,048.00	€ 0.00	€ 1,306,562.20	€ 10,829,666.43	-€ 29,502,927.77	-€ 26,760,025.19
2019	€ 51,929,840.00	€ 3,259,620.00	€ 13,925,048.00	€ 0.00	€ 2,008,776.17	€ 16,650,088.21	-€ 26,623,099.96	-€ 22,998,034.74
2020	€ 53,181,840.00	€ 4,373,622.00	€ 13,925,048.00	€ 0.00	€ 2,707,428.36	€ 23,178,868.70	-€ 23,158,973.67	-€ 19,052,944.95
2021	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,402,518.76	€ 30,476,463.51	€ 35,481,518.75	€ 27,800,698.37
2022	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,385,251.84	€ 30,321,897.38	€ 35,344,219.54	€ 26,374,400.80
2023	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,367,984.92	€ 30,167,331.25	€ 35,206,920.33	€ 25,020,900.97
2024	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,350,717.99	€ 30,012,765.11	€ 35,069,621.12	€ 23,736,499.99
2025	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,333,451.07	€ 29,858,198.98	€ 34,932,321.91	€ 22,517,686.17
2026	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,316,184.15	€ 29,703,632.85	€ 34,795,022.70	€ 21,361,125.59
2027	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,298,917.23	€ 29,549,066.72	€ 34,657,723.49	€ 20,263,653.13
2028	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,281,650.31	€ 29,394,500.59	€ 34,520,424.28	€ 19,222,263.93
2029	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,264,383.38	€ 29,239,934.45	€ 34,383,125.07	€ 18,234,105.33
2030	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,247,116.46	€ 29,085,368.32	€ 34,245,825.86	€ 17,296,469.17
2031	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,229,849.54	€ 28,930,802.19	€ 34,108,526.65	€ 16,406,784.51
2032	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,212,582.62	€ 28,776,236.06	€ 33,971,227.44	€ 15,562,610.71
2033	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,195,315.70	€ 28,621,669.93	€ 33,833,928.23	€ 14,761,630.82
2034	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,178,048.77	€ 28,467,103.79	€ 33,696,629.02	€ 14,001,645.36
2035	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,160,781.85	€ 28,312,537.66	€ 33,559,329.81	€ 13,280,566.38
2036	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 7,783,020.00	€ 3,143,514.93	€ 28,157,971.53	€ 41,205,050.60	€ 15,529,750.21
2037	€ 0.00	€ 4,430,934.00	€ 13,925,048.00	€ 7,679,700.00	€ 2,559,054.34	€ 23,302,122.71	€ 37,916,882.37	€ 13,609,975.42
2038	€ 0.00	€ 3,344,394.00	€ 13,925,048.00	€ 7,616,700.00	€ 1,934,050.13	€ 18,110,221.13	€ 34,373,525.00	€ 11,750,585.09
2039	€ 0.00	€ 2,257,854.00	€ 13,925,048.00	€ 7,789,476.00	€ 1,285,804.97	€ 12,725,682.89	€ 30,896,547.92	€ 10,059,029.45
2040	€ 0.00	€ 1,143,852.00	€ 13,925,048.00	€ 7,977,276.00	€ 641,121.59	€ 6,706,944.85	€ 26,824,295.26	€ 8,317,353.18

Minimum Real SDR Scenario : SNPV=416,309,917.00 € / Real SRR=13.62%								
Years	**Investment Cost**	**Total O&M Costs**	**Total Revenues**	**Salvage Value**	**Total External Costs**	**Total External Benefits**	**Net Social Benefits**	**Present Value of NSB**
2016	€ 51,886,800.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	-€ 51,886,800.00	-€ 51,886,800.00
2017	€ 51,198,000.00	€ 1,086,540.00	€ 13,925,048.00	€ 0.00	€ 630,567.27	€ 5,173,981.88	-€ 33,816,077.38	-€ 33,481,264.73
2018	€ 50,778,000.00	€ 2,173,080.00	€ 13,925,048.00	€ 0.00	€ 1,306,562.20	€ 10,720,710.58	-€ 29,611,883.62	-€ 29,028,412.52
2019	€ 51,929,840.00	€ 3,259,620.00	€ 13,925,048.00	€ 0.00	€ 2,008,776.17	€ 16,482,573.87	-€ 26,790,614.30	-€ 26,002,706.30
2020	€ 53,181,840.00	€ 4,373,622.00	€ 13,925,048.00	€ 0.00	€ 2,707,428.36	€ 22,666,757.86	-€ 23,671,084.50	-€ 22,747,446.94
2021	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,402,518.76	€ 29,310,258.37	€ 34,315,313.61	€ 32,649,843.46
2022	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,385,251.84	€ 29,161,573.87	€ 34,183,896.03	€ 32,202,776.38
2023	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,367,984.92	€ 29,012,889.38	€ 34,052,478.46	€ 31,761,361.47
2024	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,350,717.99	€ 28,864,204.88	€ 33,921,060.89	€ 31,325,530.62
2025	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,333,451.07	€ 28,715,520.39	€ 33,789,643.32	€ 30,895,216.53
2026	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,316,184.15	€ 28,566,835.89	€ 33,658,225.74	€ 30,470,352.68
2027	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,298,917.23	€ 28,418,151.40	€ 33,526,808.17	€ 30,050,873.34
2028	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,281,650.31	€ 28,269,466.91	€ 33,395,390.60	€ 29,636,713.51
2029	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,264,383.38	€ 28,120,782.41	€ 33,263,973.03	€ 29,227,809.00
2030	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,247,116.46	€ 27,972,097.92	€ 33,132,555.45	€ 28,824,096.33
2031	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,229,849.54	€ 27,823,413.42	€ 33,001,137.88	€ 28,425,512.78
2032	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,212,582.62	€ 27,674,728.93	€ 32,869,720.31	€ 28,031,996.36
2033	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,195,315.70	€ 27,526,044.43	€ 32,738,302.74	€ 27,643,485.80
2034	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,178,048.77	€ 27,377,359.94	€ 32,606,885.16	€ 27,259,920.56
2035	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,160,781.85	€ 27,228,675.44	€ 32,475,467.59	€ 26,881,240.78
2036	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 7,783,020.00	€ 3,143,514.93	€ 27,079,990.95	€ 40,127,070.02	€ 32,885,918.34
2037	€ 0.00	€ 4,430,934.00	€ 13,925,048.00	€ 7,679,700.00	€ 2,559,054.34	€ 22,277,322.75	€ 36,892,082.41	€ 29,935,348.65
2038	€ 0.00	€ 3,344,394.00	€ 13,925,048.00	€ 7,616,700.00	€ 1,934,050.13	€ 17,141,982.78	€ 33,405,286.65	€ 26,837,680.57
2039	€ 0.00	€ 2,257,854.00	€ 13,925,048.00	€ 7,789,476.00	€ 1,285,804.97	€ 11,815,944.23	€ 29,986,809.27	€ 23,852,761.20
2040	€ 0.00	€ 1,143,852.00	€ 13,925,048.00	€ 7,977,276.00	€ 641,121.59	€ 6,112,966.50	€ 26,230,316.91	€ 20,658,109.11

Maximum Real SDR Scenario : SNPV=122,211,765.89 € / Real SRR=13.62%								
Years	Investment Cost	Total O&M Costs	Total Revenues	Salvage Value	Total External Costs	Total External Benefits	Net Social Benefits	Present Value of NSB
2016	€ 51,886,800.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	-€ 51,886,800.00	-€ 51,886,800.00
2017	€ 51,198,000.00	€ 1,086,540.00	€ 13,925,048.00	€ 0.00	€ 630,567.27	€ 5,173,981.88	-€ 33,816,077.38	-€ 31,603,810.64
2018	€ 50,778,000.00	€ 2,173,080.00	€ 13,925,048.00	€ 0.00	€ 1,306,562.20	€ 10,720,710.58	-€ 29,611,883.62	-€ 25,864,165.97
2019	€ 51,929,840.00	€ 3,259,620.00	€ 13,925,048.00	€ 0.00	€ 2,008,776.17	€ 16,482,573.87	-€ 26,790,614.30	-€ 21,869,121.58
2020	€ 53,181,840.00	€ 4,373,622.00	€ 13,925,048.00	€ 0.00	€ 2,707,428.36	€ 22,666,757.86	-€ 23,671,084.50	-€ 18,058,557.03
2021	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,402,518.76	€ 29,310,258.37	€ 34,315,313.61	€ 24,466,344.35
2022	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,385,251.84	€ 29,161,573.87	€ 34,183,896.03	€ 22,778,173.30
2023	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,367,984.92	€ 29,012,889.38	€ 34,052,478.46	€ 21,206,172.17
2024	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,350,717.99	€ 28,864,204.88	€ 33,921,060.89	€ 19,742,366.27
2025	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,333,451.07	€ 28,715,520.39	€ 33,789,643.32	€ 18,379,327.15
2026	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,316,184.15	€ 28,566,835.89	€ 33,658,225.74	€ 17,110,135.23
2027	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,298,917.23	€ 28,418,151.40	€ 33,526,808.17	€ 15,928,345.05
2028	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,281,650.31	€ 28,269,466.91	€ 33,395,390.60	€ 14,827,952.81
2029	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,264,383.38	€ 28,120,782.41	€ 33,263,973.03	€ 13,803,366.20
2030	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,247,116.46	€ 27,972,097.92	€ 33,132,555.45	€ 12,849,376.24
2031	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,229,849.54	€ 27,823,413.42	€ 33,001,137.88	€ 11,961,131.07
2032	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,212,582.62	€ 27,674,728.93	€ 32,869,720.31	€ 11,134,111.49
2033	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,195,315.70	€ 27,526,044.43	€ 32,738,302.74	€ 10,364,108.23
2034	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,178,048.77	€ 27,377,359.94	€ 32,606,885.16	€ 9,647,200.74
2035	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 0.00	€ 3,160,781.85	€ 27,228,675.44	€ 32,475,467.59	€ 8,979,737.41
2036	€ 0.00	€ 5,517,474.00	€ 13,925,048.00	€ 7,783,020.00	€ 3,143,514.93	€ 27,079,990.95	€ 40,127,070.02	€ 10,369,597.42
2037	€ 0.00	€ 4,430,934.00	€ 13,925,048.00	€ 7,679,700.00	€ 2,559,054.34	€ 22,277,322.75	€ 36,892,082.41	€ 8,909,920.70
2038	€ 0.00	€ 3,344,394.00	€ 13,925,048.00	€ 7,616,700.00	€ 1,934,050.13	€ 17,141,982.78	€ 33,405,286.65	€ 7,540,012.98
2039	€ 0.00	€ 2,257,854.00	€ 13,925,048.00	€ 7,789,476.00	€ 1,285,804.97	€ 11,815,944.23	€ 29,986,809.27	€ 6,325,623.96
2040	€ 0.00	€ 1,143,852.00	€ 13,925,048.00	€ 7,977,276.00	€ 641,121.59	€ 6,112,966.50	€ 26,230,316.91	€ 5,171,218.32