ERASMUS UNIVERSITY ROTTERDAM

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MSc Economics & Business

Master Specialisation Financial Economics

"Economic evaluation of photovoltaic plants in Greece under the recently introduced de-escalating Feed-in-Tariff policy"

A financial report analysis investigating the economic viability of photovoltaic systems in Greece under the recently introduced legal framework and the current market conditions

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Abbreviations (alphabetically)

CdTe : Cadmiud Telloride
CF analysis: Cash Flow analysis
CIGS: Copper, Indium, Gallium, Selenide
CRES: Centre for Renewable Energy Sources
FIT: Feed-In-Tariff
GHG emissions: Greenhouse Gas emissions
HTSO S.A.: Hellenic Transmission System Operator S.A.
IEA: International Energy Agency
IRR: Internal Rate of Return
L.P.: Limited Partnership
NPV: Net Present Value
PI: Profitability Index
PPC S.A.: Public Power Corporation S.A.
PVs: PhotoVoltaicS
RAE: Regulatory Authority for Energy
RES: Renewable Energy Sources
SMP: System Marginal Price

ABSTRACT

The present paper investigates the economic viability of an investment in photovoltaics, or solar panels, in Greece. The point in time of our research is critical, as the recently introduced de-escalating Feed-In-Tariff policy signals important changes in the options of a potential investor and the Greek electricity market on the whole. The structure of the paper as financial report analysis gives intuition over the several choices available to a potential investor. The presented current market and legal background frames the potential of the investment. The analytical part in implemented under the capital budgeting methodology, including Cash Flows Analysis, NPV Analysis, IRR and robustness check with Ratio Analysis and the Simple Payback Method. Implementing the methodology mentioned and with the help of sensitivity and scenario analysis, the results illustrate the choices that a potential investor has in short-term horizon and how these choices can affect the project's efficiency.

Keywords: photovoltaic plants, policy, report analysis, investment viability, Greece

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CHAPTER 1 Introduction

In the present paper, an approach of the Photovoltaics (PVs) market in Greece is attempted under the scope of financial analysis. The present point in time is critical, as the country experiences a transition from the investment incentive law to a new de-escalating feed-in tariff policy, as from 2009. Furthermore, the recently introduced updated changes of law 3851/2010 in June 2010 promise a change in the scene of electricity market in Greece. The changes in the relevant legal framework motivated the research of the present paper; the goal is to give a complete illustration of the present market conditions and intuition over the dynamics of the financial viability of a potential investment project in PVs. As expected, little analysis of the investment project has been completed under the new legal framework; our interest focuses on the transition to the new policy and what the change could mean for the choices of the potential investor, the electricity market and the country on the whole.

1.1 The idea behind the paper

The main goal of the present paper is to shed light on a developing and highly interesting market; the energy market in Greece. The global trend looks at the Renewable Energy Sources (RES), as new investment projects are incentivized towards that direction. There are many recent policies that orientate the market to more “green” sources of energy, as the signs show that it is more than necessary to start the motivation for a sustainable life on our planet. The “green movement” focuses more and more on the sustainable energy part of the whole project. The financial aspect of the latter can be translated mainly to several incentives to investors, so that a significant pool of money would ensure a remarkable percentage of RES contribution to the total energy production.

One of those recently-implemented changing policies is spotted at Greece. We are focusing on the change of the investment frame for PhotoVoltaic (PV) panels in Greece, the last updated report of which took place in June of 2010; the country is experiencing a transition from the investment incentive law (N.3468/2006) which subsidized the project’s total initial cost with a range of grants between [30%, 60%], depending on the investment, to a de-escalating feed-in tariff (FIT) policy (law 3734/2009 and updated changes of law 3851/2010). A parallel and continuing reduction of cost of PVs systems is noticed, as new improved and promising technologies suggest easy and low-cost infrastructure for power projects or individual use.

Evidently, the specific time and place signal many differentiations, as far as the financial efficiency and viability of the investment project is concerned. The structure of the paper as a report analysis gives intuition over the several choices that the investor has to make, as well as over the information the investor has to handle in order to make these choices.

1.2 The central problem and further research questions

The central problem of the present paper is to determine the probability of viability and the profit range of an investment in PVs in Greece, under the current market and project-specific conditions. In order to answer the central problem, we have to focus on the total project's efficiency measurement. The central problem of the thesis can be summarized by the testing of the hypothesis:

"If an investment project in PVs is economically viable in Greece, under the new de-escalating FIT policy and under the current market conditions"

The main research question concerns the viability of an investment project of PVs in Greece at this critical point of time. Further research questions that lead to the answer of the central problem are detected in the chapters of the report analysis that follow. The main research sub-questions could be summarized below:

- Which are the parts of an investment project in PV panels in Greece?
- How is the efficiency of solar energy use shaped in Greece?
- Which are the technological alternatives for the PV power project?
- Which is the potential cost of an investment project in PV panels in Greece?
- Which are the current conditions that define the market background of the investment project?
- Which is the legal background that defines the policy framework of the investment project?
- Which are the choices available to a potential investor in PVs and how do they affect the project's efficiency?

The main research question and sub-questions help the construction of a benchmark model and the determination of the project's basic parameters. The financial efficiency of the particular model has to be tested and the critical values for which the project is economically viable will give a clear answer to the main hypothesis.

The basic extensions of the present report analysis are the sensitivity analysis, with the change of the basic input parameters, and the scenario analysis. Moreover, the robustness of the results is checked with the use of additional measures of economic valuation (Ratio Analysis and Simple Payback Method), apart from the use of the basic Cash Flows analysis.

We already mentioned that we structured our research according to the directions of a financial report analysis; in chapter 2 we give a short description of the investment project and while making some choices and assumptions, we build the benchmark model that tests our main hypothesis. In chapter 3, we describe the current market conditions and the legal framework of an investment project in PVs. In chapter 4, we determine and explain the choice of the methodology that leads to the results of the financial analysis. Finally, in chapter 5, the results of the implemented methodology are given and explained.

CHAPTER 2 Investment Project-Model Constructions

In this chapter we give the necessary description of the investment project, namely an investment in solar panels in Greece. Starting with the substantial part of a report analysis, we try to approximate the current levels of cost needed to implement the particular investment and describe every project-specific aspect. Through this description, we discover several alternatives that could be included in the project and are mentioned in each section. However, in order to test our initial hypothesis, we have to make some choices, on behalf of the investor, and build a benchmark model based on these assumptions. In this chapter we include most of the assumptions and the initial parameters, which are needed to test our hypothesis and to conclude over the project's performance. Extensions with sensitivity analyses and the use of input alternatives are given in chapter 5.

2.1 Description of the project

2.1.1 The project's goal

The implementation of the particular investment project aims at taking advantage of the "green" sources of energy, namely solar energy, so as to produce electricity with the use of grid connected photovoltaic modules. Electricity, as output product, will be provided for sale directly (without any intermediate stage of storage) to the Greek Public State and more particularly to HTSO (Hellenic Transmission System Operator S.A.). However, the future scenario of giving the generated electricity for sale to a third party is not excluded, provided that the project looks at a long-term horizon and that the deregulation of the electricity market in Greece is feasible.

The objective of the project arises mainly from the fact that the investors may benefit from the implementation of a long-term investment with certain efficiency, which actually depends on new technologies and does not require much of the investor's daily time to track the implemented activities.

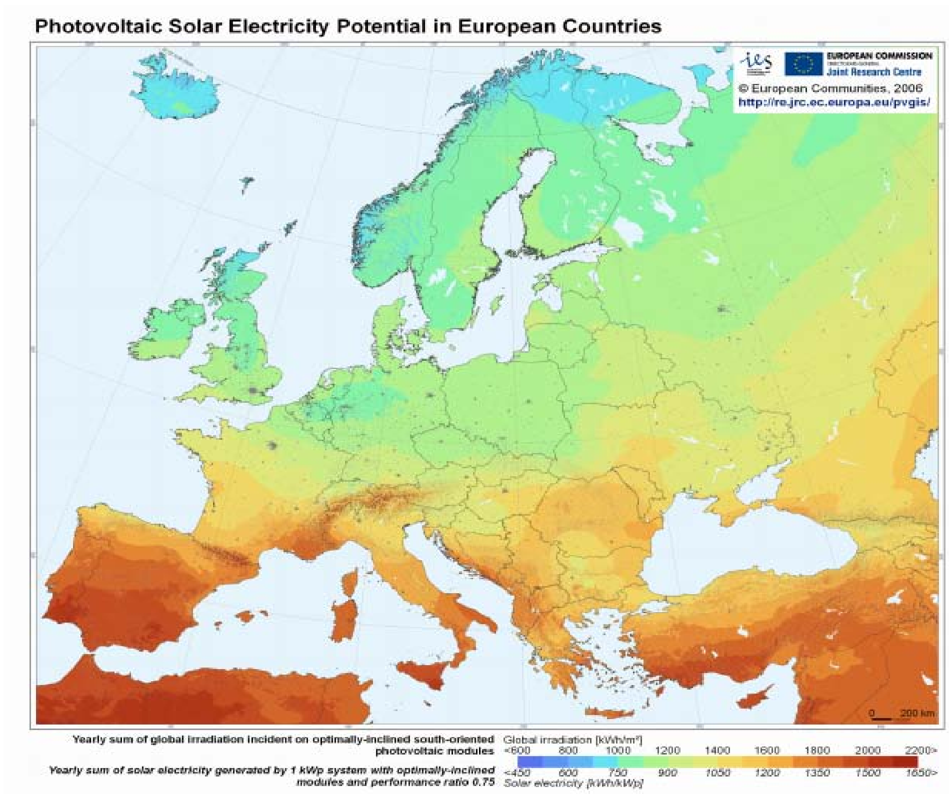
Until January 2010, an investment project in PVs in Greece could have aimed at taking advantages of the beneficial framework of the investment incentive law, under which the initial cost of the investment is subsidized. However, the transition to the de-escalating FIT policy has multilateral parameters that need to be analyzed as far as the economic efficiency is concerned. Moreover, there are not complete updated reports and forecasts over the future of an investment project of PVs in Greece under the new policy and the evolution of the market indexes. In the present paper we are investigating whether the new policy and its possible evolution in the next years still make the investment project beneficial for the investor.

Moreover, we should take into account that the project contributes to the support of the country's secure supply of electricity; distributed generation, namely micro grids of local power generation projects, assure homogeneous supply over Greece. The latter enhances the efficiency of the whole electricity system, as remarkable losses during the transportation and distribution of electricity are avoided. The secure supply of electricity becomes more and more important as the increase in electricity demand is noted with a remarkable rate of annual growth of consumption of around 4% (see section 3.2.3) apart from the fact that black outs are also possible in certain areas. Distributed generation can be proven economically beneficial for the power projects and could actually contribute to the reduction of locally "versatile" levels of electricity demand.

2.1.2 RES: Why solar energy, why PVs?

There are certain indications and facts that could orientate potential investors to a project in PVs instead of other projects in RES. First of all solar panels can be installed practically in every flat surface, inclined or not. The input needed for the power generation, namely solar energy, is widely available and inexhaustible. Scanning Figure 2.1, which provides an illustration of the photovoltaic solar electricity potential in Europe, it is more than apparent that Greece and the other countries of Mediterranean are favored but their geographical position.

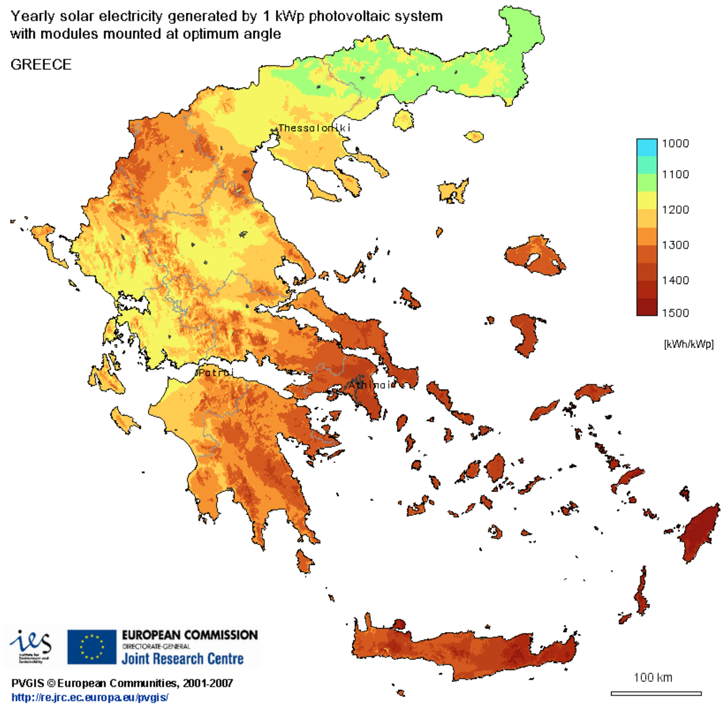
Figure 2.1: Photovoltaic Solar Electricity Potential in European Countries



Source: http://re.jrc.ec.europa.eu/pvgis/cmaps

Continuing with Figure 2.2, we may prove that it is possible for North Greece to produce around 1,150 kWh per kWp and a level of around 1,450 kWh per kWp for South Greece (where kWp is kilowatt-peak, a measure of the peak output of a photovoltaic system); the levels are remarkable and may be efficiently exploited for solar energy projects. Moreover, we should not ignore the fact that incentivized investments in other European countries, with lower electricity generation potential, have been bloomed the last years. On the other hand, input sources of other RES can be exhaustible (i.e. water power for a hydroelectric project) or there are restrictions such as the inevitable high levels of wind power production dynamics or the requirements of big surface for the exploitation of biomass.

Figure 2.2: Yearly solar electricity generated by 1kWp photovoltaic system with modules mounted at optimum angle



Source: http://re.jrc.ec.europa.eu/pvgis/cmaps

PV projects are technically implemented more quickly and easier, when compared to other RES projects. This is due to technological advances in the field, as the projects consist only of panels with metallic bases, moving or stable. On the contrary, wind parks or hydroelectric projects require complex constructions in often isolated and not accessible areas, as mountains, rivers, etc. Apart from the increased difficulties, these requirements lead to a remarkable increase in the cost of the project (initial, transportation or maintenance cost).

PV projects function with little human occupation, as the need for maintenance and supervision is minimized by the technological advances. Moreover, remote monitoring is possible, which actually reduces the time that the investor or manager has to devote to the control of daily works of the power system.

Finally, PV projects have a significant advantage when compared to other RES projects; due to the fact that solar energy is used as an input, the electricity produced follows on average the pattern of daily electricity demand. This means simply that the energy generated reaches the maximum levels when it is indeed needed, namely during the day-time. The latter makes PV projects favorable as a technical solution for energy demand, throughout the daily distribution of loads.

2.1.3 Output product: electricity

The output product is, apparently, electricity. The electricity produced, after measurement, will be disposed at the connected national electricity network and the total revenues depend on the quantity of electricity that the network will absorb. Thus, the infrastructure does not need to include a part for electricity storage (i.e. batteries) for a subsequent use. It is more convenient to connect the project with the local network, so that all the electricity produced is directed, without any further intervention, from production to consumption.

2.1.4 Input raw material

The unique input raw material of the PV power system is solar energy, which is inexhaustible and widely available in Greece, as proven by Figure 2.2. According to photoelectric phenomenon, the solar energy is transformed into electricity with the help of PV panels. PV panels produce direct current (DC). There are projects where the DC is stored in batteries, but the energy losses are unavoidable. There is a device called an inverter, which transforms the DC to AC. Generally, in order that the photovoltaic power system work, several parts of equipment are needed: a set of interconnected elements such as photovoltaic modules, inverters that convert the DC produced by the modules into AC and all installation and control components to support the photovoltaic power capacity. The typology is different according to each application. The production process is explained in details in section 2.2.1.

What needs to be emphasized at this point is that there is not a problem of availability, thus there is not an issue of prices of input raw materials for the project. PV power systems are “passive” systems, meaning that they simply convert the solar irradiation to electricity, without the possibility of scaled use of the input raw material.

The fact that solar energy is abundant in Greece increases the potential of economic viability of the project. Moreover, the change of the intensity of solar energy during the summer months is considered to be particularly positive for the investment project, as we spot high levels of energy consumption in the country at this period of time. There is evidence that in Greece, as well as in the rest of Mediterranean countries, there are two peaks of electricity demand in December-January and July

(Hekkenberg et al., 2009). It is expected that during summer there is high energy demand, as the temperatures in the country are very high and air conditioning is widely used.

2.1.5 Brief presentation of the technical components of the project

In the next six sub-sections we briefly present the technical components of the project, extended description of which is included in section 2.2.

PV technology comparison

In the world of PV solar power, there are several types of semiconductor technologies currently in use for PV panels. Two, however, have become the most widely adopted: crystalline silicon and thin film. The efficiency of each solar panel is measured by its ability to absorb light particles called photons. The more photons are being absorbed, the more efficient the panel is at converting light into electricity.

Crystalline silicon panels are made from thin slices cut from a single crystal of silicon (monocrystalline) or from a block of silicon crystals (multicrystalline). These cells are then assembled together in multiples to make a solar panel. Crystalline silicon, also called wafer silicon, is the oldest and the most widely used material in commercial solar panels. Thanks to the related experience of the electronics industry, they dominate the PV market at present. In 1993 they had 84% of market share (Vigotti 1994a) and they represent about 90% of the market today. Their efficiency ranges between 12% and 17%. The cost of running PV power systems with crystalline technology is divided in 73% modules and 27% "Balance-of-System" (BOS) costs, meaning DC-Cables, engineering, substructure, installation, and inverters.

There are two types of crystalline silicon panels:

- *Monocrystalline* (also called single crystal) panels use solar cells that are cut from a piece of silicon grown from a single, uniform crystal. Monocrystalline panels are among the most efficient, yet most expensive on the market. They require the highest purity silicon and have the most involved manufacturing process.
- Multicrystalline (also called polycrystalline) panels use solar cells that are cut from multifaceted silicon crystals. They are less uniform in appearance than monocrystalline cells, resembling pieces of shattered glass. These are the most common solar panels on the market, being less expensive than monocrystalline silicon. They are also less efficient, though the performance gap has begun to close in recent years.

Thin film solar panels are made by placing thin layers of semiconductor material onto various surfaces, usually on glass. The term *thin film* refers to the amount of semiconductor material used, which is thinner than the width of a human hair. Thin film solar panels offer the lowest manufacturing costs, and are becoming more prevalent in the industry. Thin-film manufacturing processes result in lower production costs compared to the more material-intensive crystalline technology, a price advantage that is currently counterbalanced by substantially lower efficiency rates (from 5% to 13% lower levels). The cost of running power projects with thin-film technology is divided in 52% modules and 48% BOS costs.

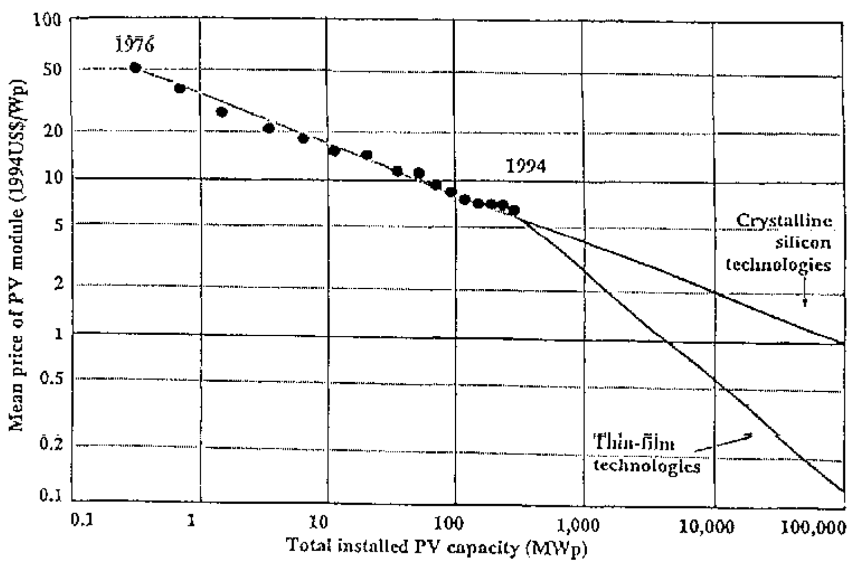
There are three main types of thin film used:

- *Cadmiud Telloride (CdTe)* is a semiconductor compound formed from cadmium and tellurium. CdTe solar panels are manufactured on glass. They are the most common type of thin film solar panel on the market and the most cost effective to manufacture. Today, CdTe is not as efficient as crystalline silicon, but CdTe panels perform significantly better in high temperatures due to a lower temperature coefficient. It also provides superior energy output in low, indirect, and diffused light conditions, producing more electricity on cloudy days. Only 1-2% of the semiconductor material used in traditional crystalline silicon solar panels is needed, eliminating a major cost component.
- *Amorphous silicon* is the non-crystalline form of silicon and was the first thin film material to yield a commercial product, first used in consumer items such as calculators. It can be deposited in thin layers onto a variety of surfaces and offers lower costs than traditional crystalline silicon, though it is less efficient at converting sunlight into electricity.
- *Copper, Indium, Gallium, Selenide (CIGS)* is a compound semiconductor that can be deposited onto many different materials. CIGS has only recently become available for small commercial applications.

Through comparative research we found out that one benefit of thin film solar panels which other types cannot offer is that they do not suffer a decrease in output when temperatures go up(already mentioned for CdTe). Some may even have a slight increase in their outputs. That is indeed impressive, since areas like Greece where sunlight is readily available are also usually hot. Because of this, thin film solar panels often have an actual output that is very close to the one they are rated for. This can make planning a solar power system much easier using this kind of panel and therefore should be considered as an option from a potential investor in Greece.

We should not ignore the remarkable cost reduction of PV technologies over the years, due to innovation and economies of scale; by scanning figure 2.3, it is evident that the history of PV cost reduction will continue. As determined by the structure of a report analysis, we have to make a choice over the technology of the benchmark model that leads to a certain level of cost. However, it is interesting to follow the evolution of cost reduction as the latter, combined with the de-escalating FIT policy will illustrate the potential of the investment project of PV power system in the future. Further comparisons with reduced costs and different choices of PV technologies that lead to different results are included in chapter 5, with the model alternative inputs of sensitivity analysis. The literature and the striking dynamics of cost reduction through the indicative figure give us the incentive to take into account the potential of the future of the investment project; a further research is completed in the sensitivity analysis section.

Figure 2.3: The Photovoltaic "learning curve"



Source: http://www.unu.edu/unupress/unupbooks/uu24ee/uu24ee0h.htm#7.%20photovoltaics

For the benchmark model, though, we assume that **multi-crystalline silicon panels** of a nominal power of **230W$_p$** are used as an intermediate and most commonly used solution: they are effective enough (more than thin panels) and less expensive than mono-crystalline panels. More details over the levels of cost are given in the cost analysis section 2.3.

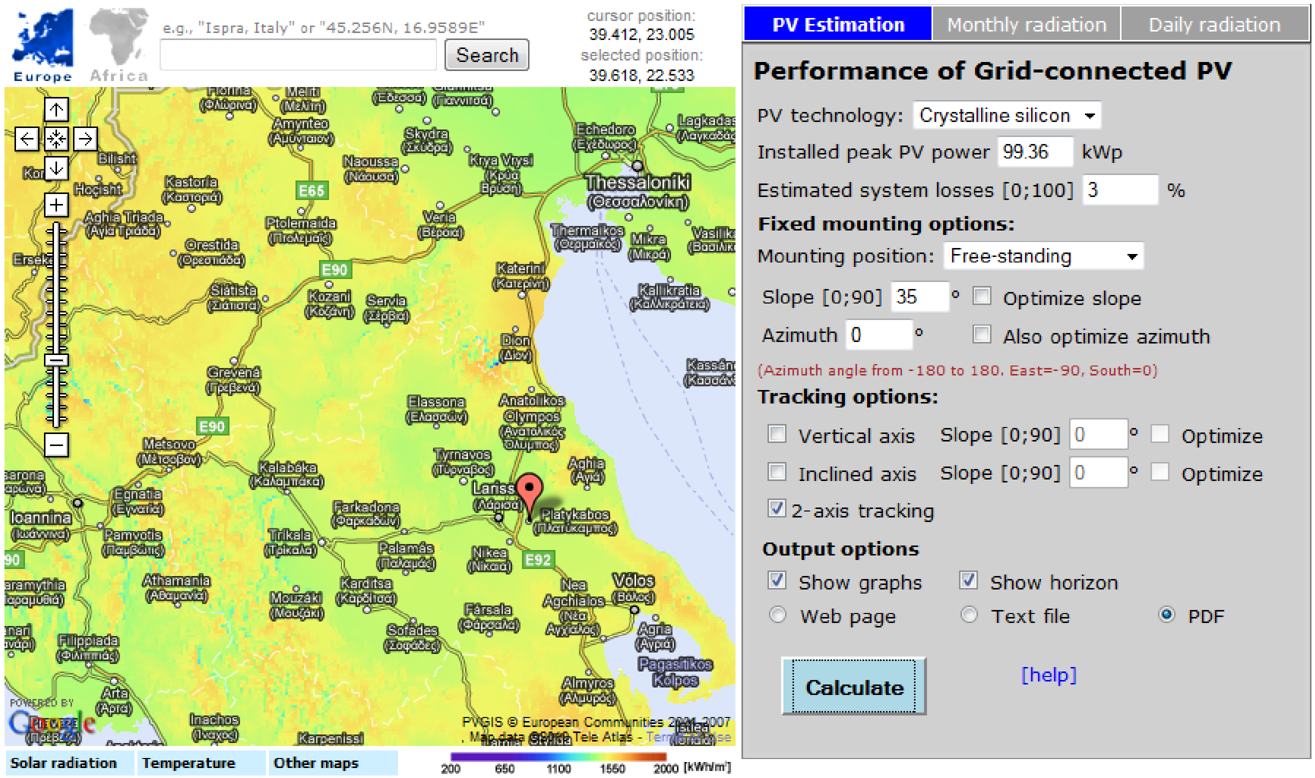
Capacity and Dynamics

The dynamics of electricity production depends on the climate characteristics of the location of the project, the inclination of the panels and the chosen technology. As mentioned in the previous section, it is suggested that the project function with PV panels of multi-crystalline technology, with nominal power of **230W$_p$**. Moreover, the benchmark model that we are building concerns a PV power system of **432 panels**, so that the total capacity is **99,36kWp**. The choice of the number of panels is related with the fact that PV projects with total capacity above 100kWp sell electricity in lower prices. The latter will be explained in details in the section 3.1.5, where the recently introduced de-escalating FIT policy is presented. Nevertheless, the choice over the total capacity as well as all the assumptions of the benchmark model are revised in the sensitivity analysis section, where we investigate the critical values for the economic viability of a PV power project. The panels will be installed with heliostat trackers, which are arrays of collectors that can be moved and "follow" the sun. The trackers allow the increase of the amount of sunlight arriving at the PV modules. It is noted that the use of trackers can increase the electricity production on average by 35%. In our case, the percentage of the increase of electricity production is estimated, with the help of Table 2.1. Finally, we should take into account that the use of trackers on not, will be treated as a differentiation in the input parameters, as implemented by the sensitivity analysis in chapter 5.

In order to estimate the electricity that can be produced by the specific PV project, we used the official source of information of European Union, PVGIS (Photovoltaic Geographical Information System - Interactive Maps, which was implemented in the research center of EU (JRC). For the purposes of estimation, we additionally assumed that there are 3% losses of the system, which aggregately cover the losses of the inverter, the cables, the diodes of the panels and possible mismatch of the characteristics of the panels, as defined by the manufacturer. The percentage is indicative and chosen after relevant research in existent projects in the same area. The relevant literature over the system's losses points at several factors that change the efficiency of the projects. However, we will not extend our research to that direction, as we can use the data from already implemented projects around the area under the directions from an experienced consulting company (*KLT Energy*).

Having all the inputs to estimate the future electricity production we implement the calculations. A snapshot of the application illustrates the initial parameters that were set for the benchmark model.

Figure 2.4: Application PVGIS: the initial parameters for the benchmark model



Source: http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php

As long as the input parameters are accurate, the application gives the estimation over the irradiation and the electricity for a project with the particular characteristics. At this point we should mention that the application incorporates some additional losses and calculates the overall losses of the system:

Estimated losses due to temperature: 10.1% (using local ambient temperature)

Estimated loss due to angular reflectance effects: 2.7%

Other losses (cables, inverter etc.): 3.0%

Combined PV system losses: **15.1%**

According to the data of the consulting company, which has taken on projects around the area (KLT Energy), the theoretically suggested percentage of losses given by the particular program is underestimation of the real efficiency; most of suppliers can offer a warrantee of 90% efficiency of the system for the first 10 years and 80% for 25 years. The approximation of the percentage of losses suggested by the software is not extremely different from the reported losses; therefore we may take into account the losses of 80% for 25 years provided that the project aims at long-term economic goals.

Given that the power system uses 2-axis trackers, the software estimated that the total electricity production is **170,000 kWh per year**, which actually means that the expected average production of the PV system per year is **1,711 kWh per installed kWp**.

At this point, we should justify our choice of installing the PV panels with trackers, by proving that they improve the efficiency of the PV power system. Using the results from the PVGIS software, we may compare the average values of electricity produced per month.

Table 2.1: Monthly levels of electricity capacity for the PV power project without and with the use of trackers (kWh/kWp)

Month	Electricity Capacity(kWh/kWp) Fixed System	Electricity Capacity(kWh/kWp) With the use of trackers
January	67.5	79.5
February	75.2	87.8
March	105.7	124.8
April	131.8	167.1
May	144.9	194.2
June	151.0	215.4
July	155.0	215.4
August	144.9	190.2
September	123.8	153.0
October	112.7	137.9
November	74.8	89.1
December	51.6	58.9

Source: http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php

Focusing on the table above, we may conclude that the use of trackers increase the electricity capacity by approximately 28% (2-axis system: 170,000kWh per year, fixed: 133,000kWh per year). The latter provides a good reason for **the use of the trackers** in our base case model. However, the sensitivity analysis in chapter 5 will show the relation between the cost and efficiency with the use or not of moving trackers.

Scaled production

Due to the nature of the technology of PV panels, scaled production is not an option. However, it is worth mentioning that because of inevitable ageing, the PV panels undergo a small reduction of the maximum power after 20-25 years. As already mentioned most of the manufacturing PV panels companies give a guarantee of 25 years, assuring 80% of the nominal maximum capacity. The latter practically means that there is **around 0.8% reduction of the capacity dynamics** per year, which we incorporate in our financial report analysis, even though the percentage does not affect the investment significantly.

Energy consequences

Apparently, the nature and the implementation of the investment project exclude energy consequences. On the contrary, the project offers energy benefits around the wide area. Given that a typical family house in Greece consumes about 5,000kWh per year (annual level of electricity consumption of 4,970 kWh per average Greek resident according to Public Power Corporation S.A. in 2007), the power dynamics corresponds to the average power of approximately 34 typical Greek residents.

Human occupation

We already mentioned that no occupation of employees is needed.

Choice of installation place and criteria

As already mentioned in section 2.1.2, the PV panels can be located in almost all flat surfaces. The basic factors for the choice of location are:

- Avoidance of any obstacle, natural or not, that could cause shadowiness on PV panels and, thus, reduction of efficiency.
- Capability of installation so that the panels are south-orientated
- Minimum additional requirements for the modification of the location, to avoid cost
- Proximity of the existent electricity network

For our benchmark model, we choose the municipality of Larissa, which is located in center-to-north of Greece. After the relative research, the area provides many opportunities for a PV power system.

2.2 Technical parts

2.2.1 Production process

Technical characteristics of input and output products

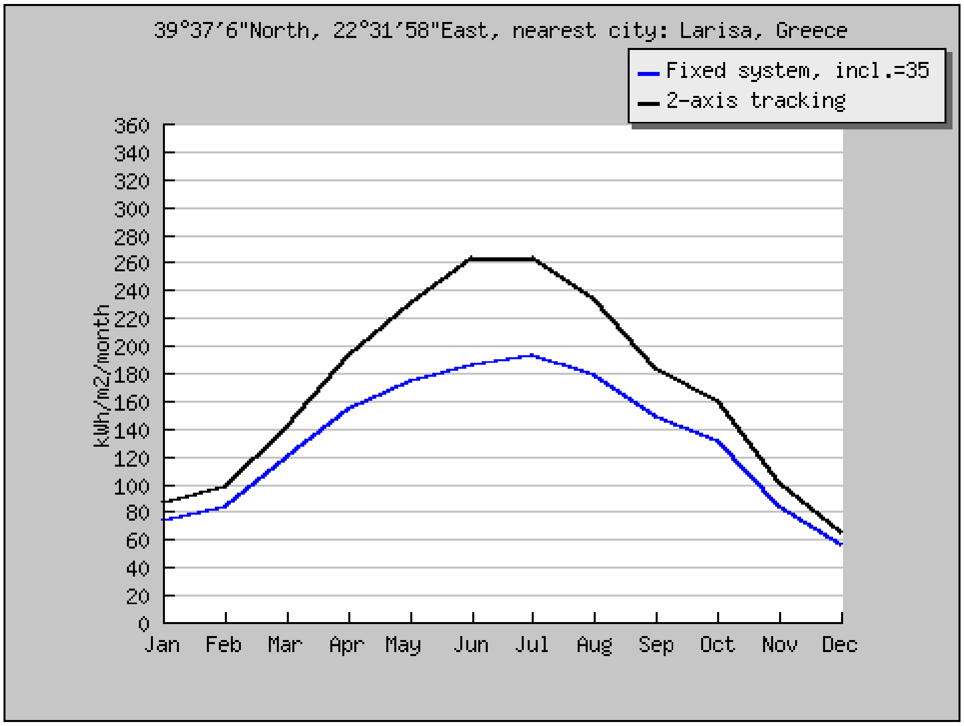
As already mentioned in section 2.1.4, the input raw material is solar energy. The most basic characteristic of solar energy is its intensity of irradiation, meaning the density of energy per surface unit. The electricity generation, with the use of PV panels, goes up and down, following the solar irradiation intensity changes, during the day-time and the four seasons.

The usable voltage from solar cells depends on the semiconductor material; in silicon, it amounts to approximately 0.5 V. Terminal voltage is only weakly dependent on light radiation, while the current intensity increases with higher luminosity. A 100 cm^2 silicon cell, for example, reaches a maximum current intensity of approximately 2 A when radiated by 1,000 W/m^2.

The output (product of electricity and voltage) of a solar cell is temperature dependent. Higher cell temperatures lead to lower output, and hence to lower efficiency. The level of efficiency indicates how much of the radiated quantity of light is converted into usable electrical energy. Therefore, an additional technical characteristic is the temperature-efficiency association of the PV cells. The manufacturers usually determine the power generation, assuming that the temperature of panels is 25^o Celsius. However, due to local micro-heating, the temperature of the cells can be $20\text{-}30^o$ Celsius higher than the temperature of the environment around. In order to show the levels of efficiency reduction due to temperature increases, the manufacturers provide a coefficient of power reduction per Celsius degree, in excess to the nominal temperature of 25^o Celsius. The system losses due to temperature are incorporated in the estimation of efficiency, as indicated by the PVGIS software results (losses due to temperature are estimated at around 10% in total).

The information given in this section proves that the production capacity of a PV power system depends on the location and climate of the area around it. We could focus on the irradiation levels of our benchmark investment project, which is estimated by the PVGIS application.

Figure 2.5: Irradiation given for the chosen location of the PV power system



Source: http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php

The figure above presents the irradiation changes, measured in kWh per square meter and per day, when “falling” onto horizontal panel (fixed system) or onto the panels with the optimal inclination (2-axis tracking). Of course, as expected, the irradiation levels are higher during the summer months. According to the same software, the values of irradiation are (per square meter and per day) 5.50kWh with the optimal inclination and 4.31kWh with the fixed system.

There are some additional technical requirements for the electricity generated which demand the use of additional equipment. The technical details concern the present analysis, but only in terms of the equipment needed, which actually is translated as the necessary input cost. The parts of the additional equipment are mentioned and analyzed in section 2.2.4.

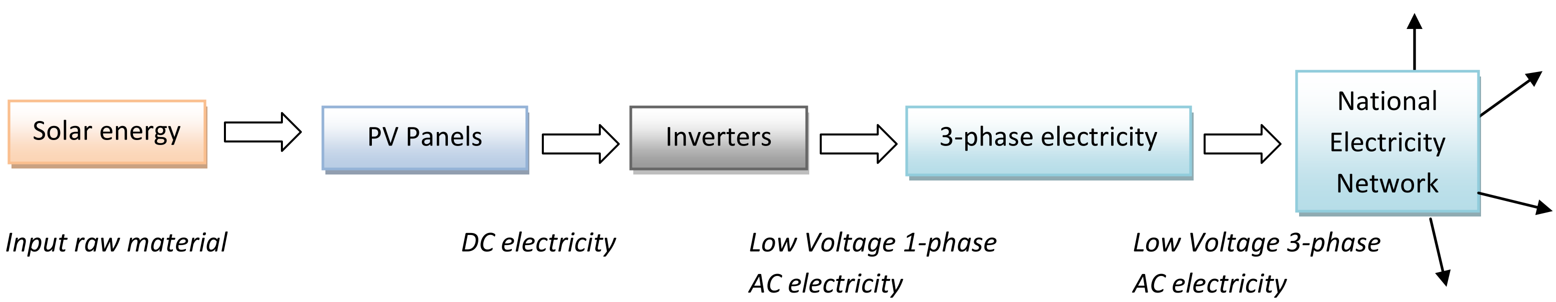
Description of production process

The electricity generation and distribution process is remarkably simple and is realized instantly.

The solar cells of PV panels are made from a semiconductor material, in our case silicon. When light strikes this material the semiconductor starts to move the electrons in the solar panels. The resulting electron activity is so strong that as the electrons flow around the semiconductor electricity begins to be produced in the solar panel. That is how solar irradiation is transformed into DC, which circulates through cables and connectors to inverters. Inverters transform DC into AC of low voltage and of 50Hz frequency. During this conversion a small bit of electricity will be lost. The single-phase voltage produced in transformed into three-phase voltage. Then, the electricity produced, after measurements, is led to the connected electricity network.

Production Flow Chart

According to the previous section, we may illustrate the production process with the flow chart below:



2.2.2 Technical equipment for the production system

The implementation of the project requires significant initial investments in technical equipment, which actually is the only "responsible" for the electricity generation. A significant decision, thus, is the choice of the supplier. Towards that objective we realized a relevant research of suppliers, focusing on the reliability, the quality, the efficiency-cost association, the maintenance services and the compatibility with the international standards.

At this point we may list all the parts of the equipment needed for the implementation of the project, as well as their basic technical characteristics and the correspondent cost.

1) **432 PV panels** of multi-crystalline silicon with nominal power of **$230W_p$**[1]

There are many offers of manufacturer companies for this kind of PV panels. It is significant to choose a manufacturer company which is reliable and provide panels with certification of quality, as determined by ISO 9001:2000. The relative research in the market concludes that the characteristics of the particular technology are appropriate for the size and location of investment.

The cost of 432 panels of that technology costs approximately **224,640 €**, given that each panel costs 520 €. While editing the present paper, there has been an updated collection of costs as the transition to FIT policy (and the abandonment of Development Law-subsidizing) created some market distortions. As a result, more "compressed" costs are now available for the project, promoting the investment. The market distortions are explained in chapter 5, as we investigate the reduced cost from January till July 2010 through sensitivity analysis.

2) **27 2-axis trackers**[2]

The 432 PV panels are installed in a string of 16 PV panel generators of total power $230kW_p$ x 16 = 3.68 kW. Every string of the panels is installed on 2-axis trackers, with a moving basis. The trackers are accompanied by a monitoring system. The panels are installed in a way that the trackers may "follow" the sun. In that way, vertical incidence of irradiation for most hours of the day is accomplished. The tracking of the horizon is realized even if the sky is cloudy, so that even low levels of irradiation are exploited for the electricity production.

Every morning the system of panels looks at East and tracks the sun, beginning with the sun rising. The movement of the bases is from East to West during the day and its orientation is south. The angle of inclination of panels can change from 20^o to 65^o so that it adjusts according to the changes of the sun spot throughout the four seasons.

The cost of 27 trackers is approximately **108,000 €**, given that each tracker of the specific technology costs around 4,000 €.

[1] Brand of panels: Sunways Solar-Module SM 210U – SM 230M
[2] Brand of trackers: Heliotropio 3, 2-axis system

3) **9 Inverters**[3]

The inverters are necessary for the administration of the electricity generated. As already explained, the inverters transform the DC of the power system to AC of low voltage, so that it can be provided to the local connection with the national electricity network.

The inverters chosen have a high grade of efficiency (above 98%), have a nominal output of 11KW each and meet all the necessary technical requirements, according to ISO 9001. Each inverter includes incorporated layouts of insulation and protection, voltage trackers and monitoring system for the frequent control of its status. Each inverter accepts as input the output of 3 trackers; therefore we need 9 inverters.

Given that each inverter costs approximately 3,250 €, the 9 inverters, needed for the investment, cost around **29,250 €**.

4) DC cable system

This part of equipment includes DC cable system (1x4mm^2), cable connectors and construction of an underground network. The DC cable system costs approximately **7,000 €**.

Summarizing all the costs mentioned above, we provide the concentrating table below:

Table 2.2: Costs for the main technical equipment of the investment project

No	Part of equipment	Pieces	Cost of piece(€)	Total Cost(€)
1	PV panels	432	520	224,640
2	Trackers	27	4,000	108,000
3	Inverters	9	3,250	29,250
4	Cable system	-	7,000	7,000
Total				**368,890**

2.2.3 Transportation and installation cost

The transportation and installation costs of the PV power project are included in the cost of the equipment, as the offers from the manufacturing companies provide transportation and installation (settlement) services.

[3] Brand of inverters: SMC 11000 TL ESS GR

2.2.4 Additional equipment

1) **Central unit** of data collection and **monitoring system**[4]

The central unit of data collection and monitoring system is used for the supervision, the illustration and storage of data. It collects constantly all the data from the power system infrastructure as an input through the inverters and provides the capability of control in real time. It also provides a user friendly interface with software (i.e. Microsoft Excel) for the user. The monitoring system costs around **1,500 €**.

2) **Alarm system**[5]

A complete alarm system is needed for the protection of the equipment and the infrastructure. The system costs around **5,500 €**.

3) Other equipment

The cost for the purchase and installation of the central table of 400V, the power communication cables, the generator unit, fuse arrays etc arises to **10,000** €.

Table 2.3: Costs of the category "Additional Equipment"

No	Part	Pieces	Cost per piece(€)	Total Cost(€)
1	**Monitoring system**	1	1,850	1,500
2	**Alarm system**	1	5,500	5,500
3	**Other Equipment**	1	13,500	10,000
Total				**17,000**

2.2.5 Location and Parcel

An approximation of the land the particular investment project needs so that it can be implemented is 4,000 square meters. From relevant research in the area, the total average cost for 4,000 square meters is **3,000 €.**

[4] Brand of monitoring system: Sunny SMA Webbox
[5] Brand of Alarm System: FBI OMNI 400

2.2.6 Environment Formation

1) **Formation** of bases /lodge

There are certain works that need to be done in the location of the project before the installation of the infrastructure; excavation works and foundation of bases. The cost of the bases formation and lodge arises to approximately **15,000 €.**

2) **Human work** over the installation

It concerns the working costs, needed for the placement and installation of the infrastructure of the investment project. This cost is estimated at **7,000 €**.

3) **Fencing**

The placement of fences around the operational area of the investment project is estimated at **8,000 €**.

4) **Lodge**

A lodge is needed for the installation and protection of electro-technical equipment (i.e. inverters). It is also needed, for cases when human presence and intervention is necessary for the control of the activities of investment project. Its cost is estimated at **2,000 €**.

Table 2.4: Cost of the category "Environment Formation"

No	Part	Total Cost(€)
1	Formation of bases/lodge	15,000
2	Installation(human work)	7,000
3	Fencing	8,000
4	Lodge	2,000
Total		**32,000**

2.2.7 Infrastructure works

Given that the PV power plant generates electricity, it is necessary to be connected with the national electricity network, so as to sell its product. Therefore, there are some works related to the connection with the network. After consulting related investment projects of the same municipality (of Larissa), the connection to the national network is feasible after the construction of new 3-phase provision of low-voltage and the installation of an electricity measuring system. The cost of the infrastructure works should be around **20,000 €**. The exact amount depends of course of the exact location of the investment project.

2.2.8 Consulting costs

An investor has to take into account the consulting costs of the investment project. The relevant research revealed that the costs consist of:

- 9,000€ for the financial report analysis, provided that it is approved for implementation
- 2,000€ for the permission from RAE (Regulatory Authority for Energy)

An additional amount of 3,000 € would have been needed for environmental reports but the updated changes of the recently introduced policy exclude this category of cost for PV systems with capacity lower than 1 MWp. However, in case we want to study the viability of projects with higher capacity than 1 MWp, we should not forget to include the environmental reports costs.

As for the benchmark model, the consulting costs arise in the total amount of **11,000€**. We should also keep in mind that the consulting costs are categorized in a financial report analysis as intangible fixed expenses and therefore should be included in the total project cost, so as to reach conclusions over the economic viability of the investment project.

2.3 Total cost of investment project

2.3.1 Cost analysis and timeframe of construction period

In this section, we try to summarize the cost of the implementation of the investment project.

Table 2.5: Investment Project Cost (Benchmark Model)

No	Cost type	Cost(€)
1	Technical equipment	368,890
2	Additional equipment	17,000
3	Environment Formation	32,000
4	Infrastructure works	20,000
5	Parcel	3,000
6	Consulting costs	11,000
Total		**451,890**

As for the timeframe of the implementation of the investment project, we provide the indicative table below:

Table 2.6: Timeframe: construction period of the investment project

Type	Value(€)	%implementation	1st year(€)
Technical Equipment	368,890	100%	368,890
Additional Equipment	17,000	100%	17,000
Infrastructure works	20,000	100%	20,000
Environment Formation	32,000	100%	32,000
Parcel	3,000	100%	3,000
Intangible fixed costs (Consulting costs)	11,000	100%	11,000
Total with consulting costs			**451,890**

The construction period of the investment project usually lasts 3-4 months, depending on the area, the transportation of technology and the size of the PV power system. For our benchmark model, we should take into consideration that the construction period lasts certainly less than one year.

2.3.2 Capital and leverage structure of the investment project

No support is provided for the particular investment project; therefore we may assume a capital structure of 25% of equity and 75% of borrowing for our benchmark model, given that the project constitutes a long-term investment with stable efficiency. However, differentiations of the capital financing of the investment project is included in the sensitivity analysis of chapter 5, taking into account the cost of borrowing.

CHAPTER 3 Market Data

3.1 Global, European and Domestic Sector Structure

3.1.1 Electricity Production

First of all, we should mention that the investment project belongs in the sector of electricity generation (code: 401.1). The electricity generation is determined by the raw material used as an input in the power plants. The most important sources that set in function the power plants are coal, oil, natural gas, biomass, residues, nuclear energy, hydroelectricity, geothermal, solar energy-PVs, solar thermal energy and other sources.

Coal, oil, natural gas and nuclear elements constitute the most used and important sources of energy in global, European and national level.

Table 3.1: Electricity Production by source (2007)

	World		EU (27)		Greece	
Production from	GWh	%	GWh	%	GWh	%
coal	8,227,950	41.44%	1,023,804	30.46%	34,676	54.61%
oil	1,114,455	5.61%	112,469	3.35%	9,642	15.19%
gas	4,126,912	20.79%	724,717	21.56%	13,774	21.69%
biomass	190,468	0.96%	74,442	2.21%	184	0.29%
waste	68,034	0.34%	30,970	0.92%	25	0.04%
nuclear	2,719,058	13.69%	935,277	27.82%	0	0.00%
hydro	3,162,165	15.93%	343,250	10.21%	3,376	5.32%
geothermal	61,819	0.31%	5,773	0.17%	0	0.00%
solar PV	4,104	0.02%	3,755	0.11%	1	0.00%
solar thermal	681	0.00%	8	0.00%	0	0.00%
wind	173,317	0.87%	104,259	3.10%	1,818	2.86%
tide	550	0.00%	519	0.02%	0	0.00%
other sources	5,358	0.03%	2,450	0.07%	0	0.00%
Total Production	**19,854,871**		**3,361,693**		**63,496**	

Source: http://www.iea.org/stats/

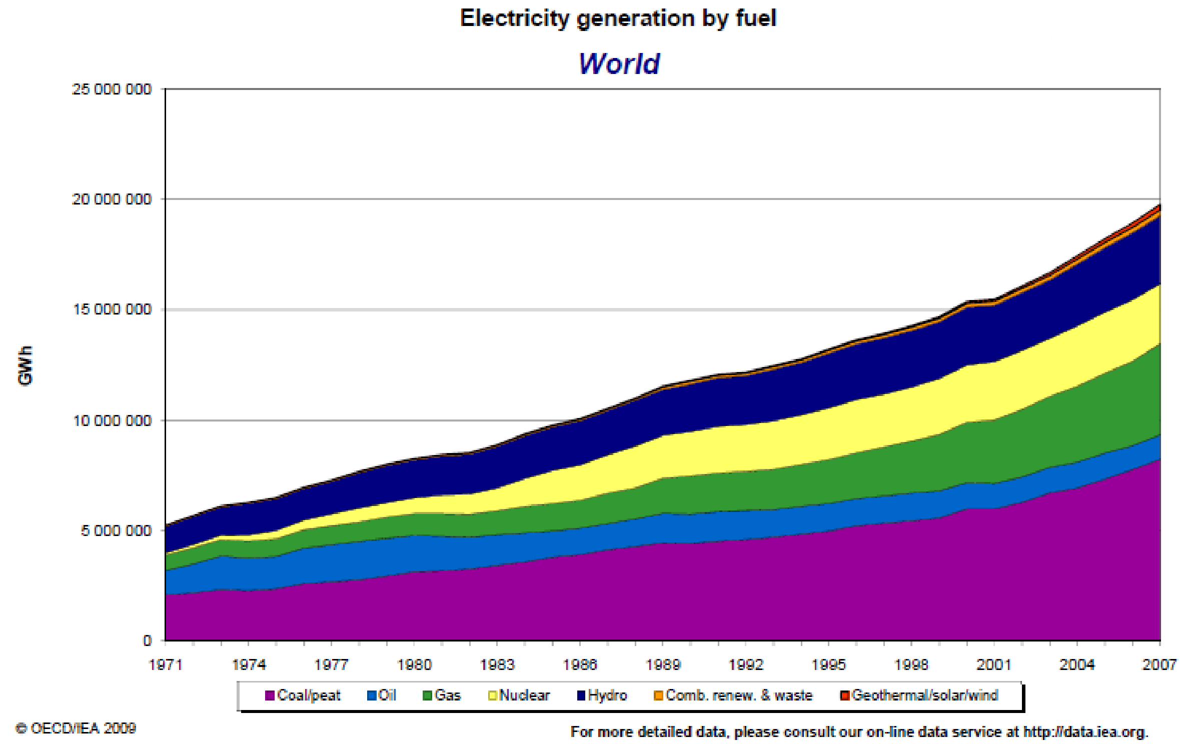
Scanning the data of the table above, around 69% of the global electricity production is derived from non-renewable resources (coal and hydrocarbons), the combustion of which produces heat, which in its turn is transformed to electricity. The use of those two sources as energy raw material has two severe disadvantages: the reserves are exhaustible and the emissions that derive from their combustion are very harmful to the environment. As widely known, the carbon dioxide (CO_2), as the most harmful emission produced by the combustion of coal and hydrocarbons, is the main contributing factor behind the global Greenhouse Gas emissions (GHG) and the global climate change that takes place the last years.

European Union's (EU) electricity production is supported by 57.5% from coal and hydrocarbons, by 27.82% from nuclear energy and only by 15% from renewable sources of energy. Nuclear energy, the percentage of which is quite striking when compared to global levels, is being approached with skepticism due to the negative consequences in cases of accidents and because of the adverse effects of nuclear waste; in case that some of these practical, though remarkable, problems are solved in the future, nuclear energy could constitute a major source of energy. Until then, the consequences that follow the electricity production with the use of nuclear energy cannot be foregone. The latter is illustrated also by the limited incentives for the development of the nuclear energy sector.

As for Greece, the mostly used source for electricity production is coal, covering 54.6% of the total production (2007 update). This percentage does not help the implementation of the country's objective to reduce the GHG emissions, so as to meet the goals of EU for reduction by 2020. The latter is not helped neither by the remarkably small use of renewable sources of energy (RES); hydrocarbons participate by 37% in electricity production, raising the total use of sources, responsible for GHG emission generation, at the high level of 92% while the corresponding global percentage is around 69%. Finally, it is worth stressing the fact that when we compare the total percentages of the contributing hydrocarbons and coal with the corresponding of 2005, we find out that the percentage not only stabilized, but even increased by 3%. At the same time, there should be taken into serious consideration that if Greece does not meet the GHG reduction goals (20% by 2020) as settled by the EU directives, there will be fees and penalties for the country.

As expected, electricity demand will go up as the years pass and the global economy grows. We provide figure 3.1 which shows the evolution of electricity generation the last 35 years. The general trend proves the increasing need for electricity generation, so as to meet the increasing global demand.

Figure 3.1: Global electricity generation evolution, by fuel (1970-2007)



Source: http://www.iea.org/stats/pdf_graphs/29ELEC.pdf

As noticed in the figure, solar energy contribution has not been significant until now; RES on the whole started evolving in 1990's but not accomplished to contribute remarkably in a global level. However, the existent numbers over the global warming problem, combined with the environmental regulations already discussed, point at certain direction; renewable and environmentally friendly sources of energy.

3.1.2 Electricity Production and RES

Renewable Energy Sources (RES), such as sunlight, wind, rain, tides, biomass, biofuels, and geothermal heat, are replenished constantly as nature defines, and are considered to be theoretically inexhaustible. The first oil price crisis in 1979 was the vaulting horse that led to the exploitation of RES, as well as to the development of reliable and efficient technologies, so that people would not totally depend on coal and hydrocarbons for their energy needs. RES have already started to be part of the world's energy balance, contributing to the reduction of dependence on the expensive and imported oil and to the energy supply security; each country can produce locally, as the resources are geographically disposable in all over the world.

The most important RES nowadays are: Urban/Municipal and industrial waste, Biomass (solid, liquid, gas), Geothermal, Solar energy, Hydroelectric power, Wind power

The distribution of electricity production with the use of RES is presented in Table 3.2.

Table 3.2: Electricity production with the use of RES (data 2007)

	World		EU(27)		Greece	
Production from	GWh	%	GWh	%	GWh	%
municipal waste	56,561	2%	27,356	5%	0	0%
Industrial waste	11,473	0%	3,614	1%	25	0%
primary solid biomass	158,237	4%	52,332	9%	0	0%
biogas	28,669	1%	18,632	3%	184	3%
liquid biofuels	3,562	0%	3,478	1%	0	0%
geothermal	61,819	2%	5,773	1%	0	0%
solar thermal	681	0%	8	0%	0	0%
hydro	3,162,165	86%	343,250	61%	3,376	62%
solar photovoltaics	4,104	0%	3,755	1%	1	0%
tide, wave, ocean	550	0%	519	0%	0	0%
wind	173,317	5%	104,259	19%	1,818	34%
Total	**3,661,138**		**562,976**		**5,404**	

Source: http://www.iea.org/stats/

Hydroelectric power constitutes the main RES for electricity production in global, European and Greek level. Globally, it covers 86% of total electricity production and 14.5% of the total electricity production. The development of hydroelectricity can be explained by the fact that the infrastructure, needed for the development of a hydroelectric power plant, has multilateral benefits (use of dams and exploitation of the valuable water) and covers large-scale projects. Biomass, even though it started as the main source of energy from the start of human history, today covers 4% of the total electricity production with the use of RES.

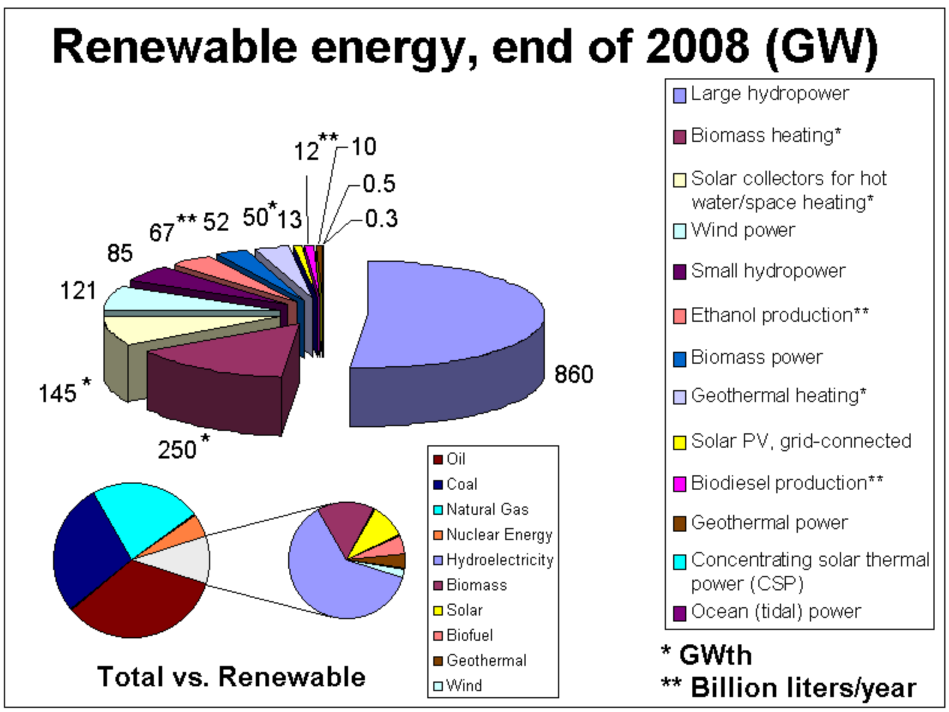
In EU, after the mostly used RES which is again hydroelectric power (61%), wind power follows covering 19% of the total electricity production with the use of RES. Wind power, wherever can be efficiently exploitable, constitutes an economically viable solution, as its technology is rapidly developing.

In Greece, the main RES for the electricity production is also hydroelectric power, which covers 62%. The wind follows, covering 34% of the total electricity production with the use of RES. As noted in the latter update of IEA in 2007, solar energy and PV panels hardly existed in the country's electricity production map.

Trying to approach the data of Greece, we may comment that the use of RES in each country is in function with the availability of the input raw material and the cost of technology. That is the reason why PVs have not entered powerfully the energy market, mainly because of their cost of technology. In Greece, an additional reason can be considered, though; the bureaucratic procedures combined with the regulation of the market discouraged many investors from the particular direction.

In figure 3.2 we provide a more recent and concentrating illustration of the global RES distribution, which confirms the tables above.

Figure 3.2: The global distribution of RES, at the end of 2008



Source: http://www.ren21.net/pdf/RE_GSR_2009_Update.pdf

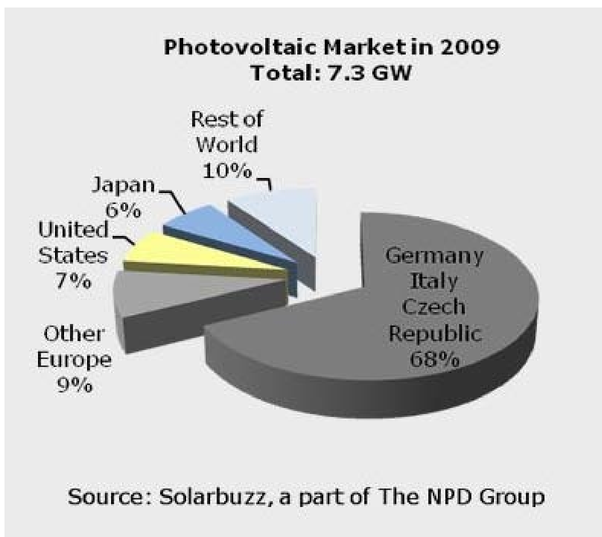
3.1.3 Global PVs market

PV technology has been first used in 1960's in space applications. Since then, the related technology has tried to cover small energy needs, especially in small and isolated locations.

The environmental advantages of PVs results are indisputable. One typical PV power system of 1KW deters the emission of 1.4 tons of carbon dioxide; to illustrate the importance of the latter we can comment that the same amount of carbon dioxide can be absorbed by two acres of forest. Moreover, it contributes to the reduction of other harmful emissions, such as small particles, ozone oxide, sulphur emissions etc.

World solar PVs market installations reached a record high of 5.95 GW in 2008, representing growth of 110% over the previous year leading to the impressive 7.3 GW in 2009, representing growth of 20% over the previous year. In the assessment of PVs demand in 2008, 81 countries contributed to the 5.95GW world market total, noting a remarkable increase of 240% when compared to 2007 (1.744 GW).

Figure 3.3: PV market demand in 2009



Source: http://www.solarbuzz.com/Marketbuzz2010-intro.htm

Overall, the PVs industry generated $38.5 billion in global revenues in 2009, increasing by 8% when compared to 2008.

European countries accounted for 5.6 GW, or 77% of world demand in 2009. The top three countries in Europe were Germany, Italy and Czech Republic, which collectively accounted for 4.07 GW. All three countries experienced soaring demand, with Italy becoming the second largest market in the world. The third largest market in the world was the United States, which grew by 36% from 2008, reaching 485 MW and noting 3% of the total market share. Following closely behind was a rejuvenated Japan, which took fourth spot, growing by 109% from 2008.

It is worth mentioning though that percentages are evolving quite dynamically; in 2008 Europe accounted for 82% of world PVs demand and Spain's 285% growth pushed Germany into second place in the market ranking, while the US advanced to number three; Spanish demand in 2009 collapsed to just 4% of its prior year level which led to its reduced market share. The constantly changing dynamics of market is explained by the critical point in time; investment incentives and the so-called "green movement" mainly of the developed countries advance the market growth and consequently the demand.

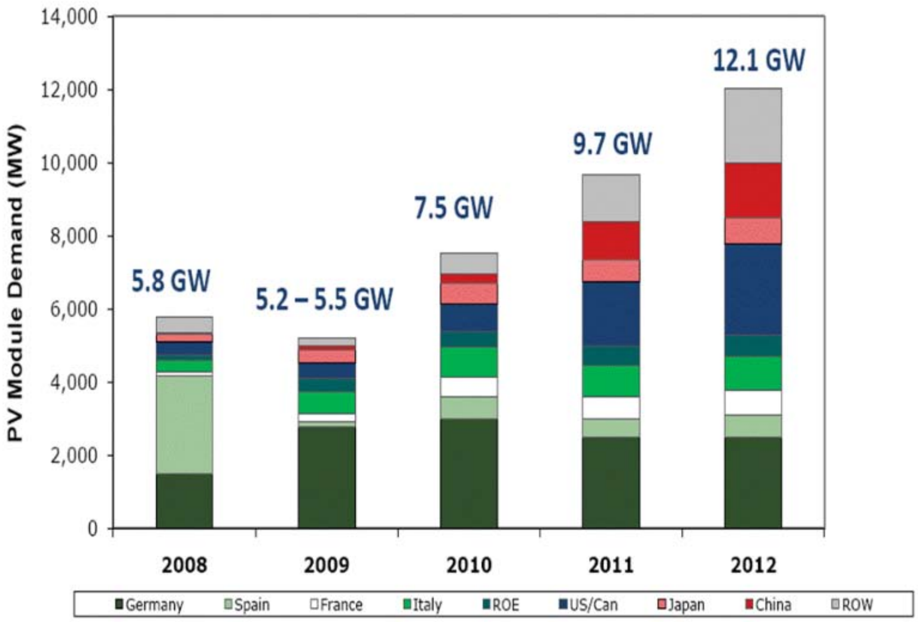
World solar cell production reached a consolidated figure of 9.34 GW in 2009, up from 6.85 GW a year earlier, with thin film production accounting for 18% of that total. Crystalline silicon panels continue to dominate the market. However, the excess of solar cell production over market demand caused crystalline silicon module price average for 2009 to crash 38% over the prior year level. This reduction in crystalline silicon prices also had the effect of eroding their percentage premium to thin film factory pricing; thin film production recorded a solid growth, up 123% in 2008.

Looking forward, the industry is forecasted to return to high growth in 2010 and also over the next 5 years. Even in the slowest growth scenario, the global market will be 2.5 times its current size by 2014 (Marketbuzz solar PV industry report, 2010). We should not ignore the fact that one basic characteristic of the PV market conditions is the fact that demand is rocketing due to the successful implemented PV applications of Germany and Japan; "leapfrogging" plays a crucial role at the PVs industry. Over the steps of these countries, Chinese and Taiwanese production continued to build share and now account for 49% of global cell production.

As indicated by the numbers, PVs constitute a potentially prosperous technology of energy production, which is expected to grow. The policies implemented and the incentives provided to investors seem to be efficient, as the figure 3.4 shows; the PV modules demand is projected to grow over 100% by 2012 across the world, when compared to 2009 estimations. Evidently, the reduced demand of PV module demand in 2009 is not related to the sector, but possibly to the global recession that followed the crisis of 2008.

The extended reference to PVs world demand and supply is connected with the evolution of PV modules market prices, overall growth and the efficiency of incentives that are provided to investors of PV power systems in all over the world in the next years. The trends show remarkable growth of the market.

Figure 3.4: Estimations and projected future estimations of PV module demand in MW (2008-2012) across several countries



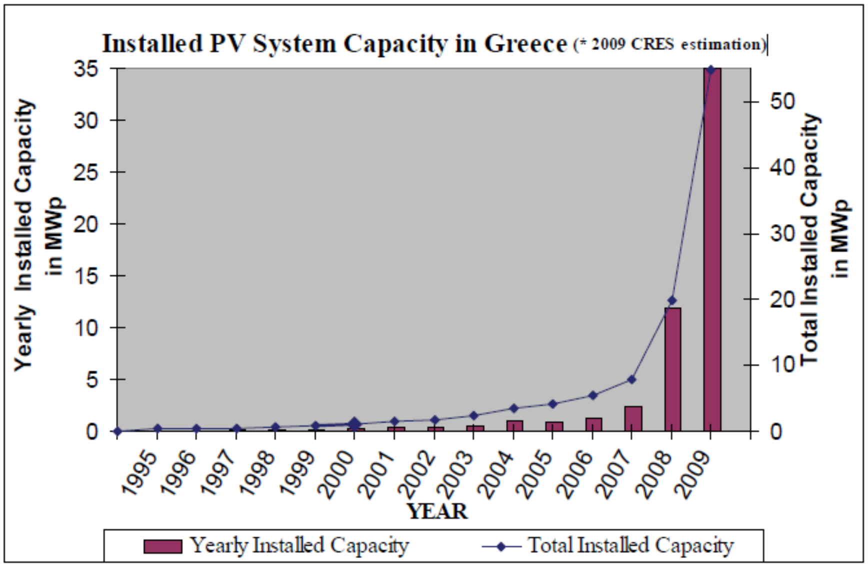
Source: First Solar Corporate Overview, 01/03/2010

3.1.4 Greek PVs market

Until recently, the installed PV systems in Greece were mainly privately owned autonomous systems in remote locations, where there is no electric grid, whereas the grid connected market was relatively small until 2006. Although there was a quite legal framework for the RES market since 1998 (national development law 2601/98, national operational program for competitiveness and several tax incentives) the lack of a significant support scheme running over a long time, the involvement of many public services in order to receive a large number of licenses and the lack of concrete regulations for the market players have hampered the larger introduction of PV systems.

The annual installed capacity of PV systems in Greece before 2006, excluding demonstration programs and research projects, did not exceed 200 to 300 kWp. Figure 3.5, presents the installed capacity of PV systems in Greece until 2009 according to the estimates of CRES (Center for Renewable Energy Sources). Between 2008 and 2009, the installed PV system capacity was raised by 12 MWp, most of it coming from grid-connected PV systems due to the law 3468/2006. (See details in section 3.1.6)

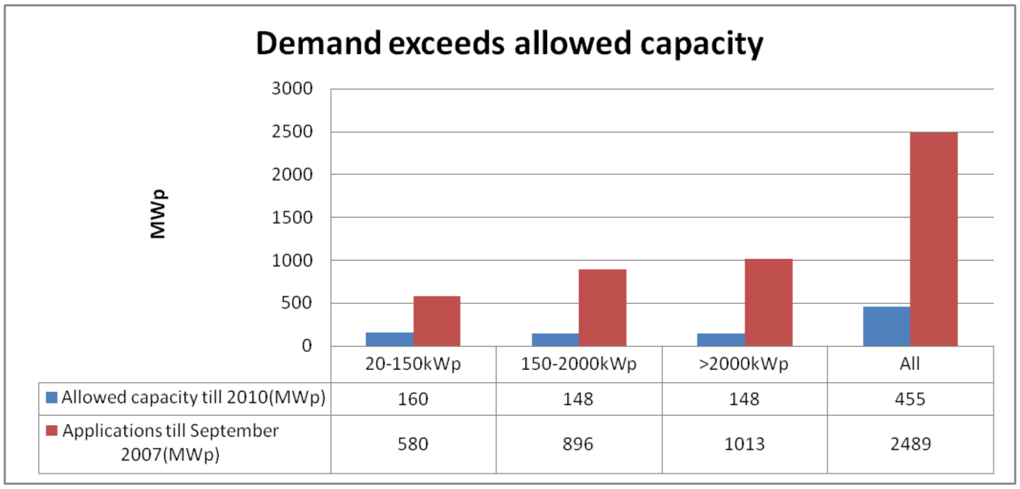
Figure 3.5: Installed PV System Capacity in Greece (2009 CRES estimation)



Source: http://www.cres.gr/kape/publications/photovol/new/6DV.2.4preprrintf.pdf

Another important characteristic of the market is the fact that the periodic license-freeze from RAE (Regulatory Authority for Energy) cause distortions at the association applications for implementation and allowed capacity. In other words, demand exceeds capacity. Bureaucratic delays make the procedure even more difficult, discouraging the potential investors. In figure 3.6 we illustrate the problem that exists in the country using the data from the allowed capacity until 2010 and the applications provided at RAE until September of 2007. We may notice that the applications always exceed the capacity that RAE allows for the different categories of kWp, causing more problems; more particularly we notice that the gap is growing as the class of kWp is increasing, due to the fact that there have been many applications for large scale projects until 2007. We should not ignore the bureaucratic parameter in the whole project-specific procedure as the latter constitutes the main reason, combined with the high cost of PVs technology until recently, for the absence of PVs power systems in electricity generation in Greece. However, as analyzed in section 3.1.6, certain bureaucratic factors that discouraged many potential investors of PV power projects are partly solved, enhancing the scenarios for large growth of PVs Greek market in the near future.

Figure 3.6: Allowed capacity until 2010 and applications until September 2007, *Demand exceeds allowed capacity*



Soure: http://www.helapco.gr/library/Greek_PV_Market_Status_Sep07.pdf

The concluding remarks over the Greek PVs market can be summarized by the fact that it can be characterized as an emerging market with great potential. Despite its excellent solar resources, the country had little progress until recently with regard to PVs; the market was marginal until 2006 and mainly based on off-grid systems. However, the recently introduced policy (de-escalating FIT scheme, see section 3.1.6) completely changed the picture and signaled changes in the dynamics of the market. We expect that the new de-escalating FIT policy, combined with the fact that bureaucratic problems are solved under the new legal framework, will promote a large pool of investments in the near future; the investors interested in the sector want to benefit from the higher prices of the tariff policy and will probably enter the market as soon as possible.

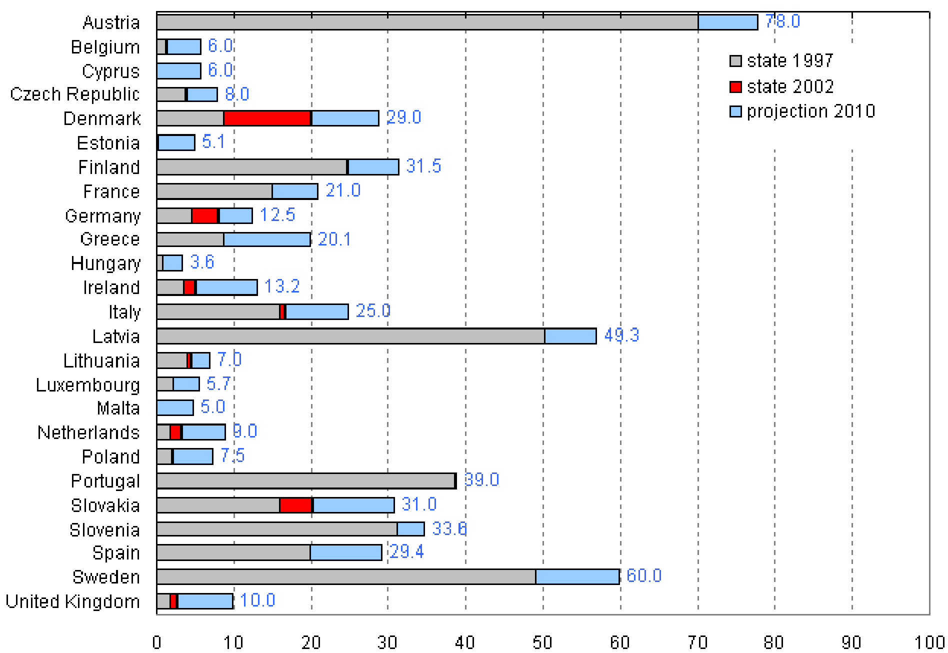
There is already a huge interest in all sectors of the market: manufacturers, wholesalers, retailers, integrators, project developers, consultants, as well as the financial sector (banks and insurers); a 4 billion € PV market is expected to be developed in the coming years in Greece (Hellenic Association of Photovoltaic Companies, The Greek PV market, 2007).

3.1.5 Current Policies for PV projects in EU

The starting point for the consideration of RES and their integration into the EU's policies was the presentation of strategic goals for 2000-2005; the commission characterized energy as determinant factor for competitiveness and economic growth of EU. The strategic goals were established with two important papers; the White Paper in 1997 and the Green Paper in 2000. These two papers are known as authoritative reports edited by the European Parliament that addresses issues and intent to solve them. For the first time, the two papers orientated issues towards the RES development in EU.

White Paper: According to the White Paper COM (97)599 of 1997 "Energy for the future-renewable sources of energy", the EU strategic plan over RES was shaped. The principal goal was to double the share of RES in gross domestic consumption of energy in EU, from 6% in 1997 to 12% in 2010, and in September of 2001 a new directive of the parliament promoted the electricity production from RES. EU intents to increase the percentage of "green" energy from 14% of 1997 to 22% in 2010. Figure 3.7 shows the relevant data and the percentage of Greece is detected to be 20.1%

Figure 3.7: Share of renewables on total national electricity consumptions [%] in the EU25: the state and indicative targets for 2010 according to the Directive 2001/77/EC and the related documents



Source: http://re.jrc.ec.europa.eu/pvgis/restat/restat.htm#PV%20power

Continuing with EU projected targets and data over RES, as defined by the White Paper, we provide Table 3.3. As can be seen in the table below, PVs hardly existed in the RES map of EU in 1995; however, the target of the projected increase by 100% was set with the policy as defined by the White paper of 1997, which is evidently translated as very positive development for PVs.

Table 3.3: Electricity generation from renewables (TWh) in 1995 and indicative targets for 2010 in EU15 according to the White Paper COM (97)599

Type of RE	1995		2010		projected increase
	TWh	share %	TWh	share %	
Hydro	307	13.0	355	12.4	1.2
Biomass	22.5	1.0	230	8.0	10
Wind	4	0.2	80	2.8	20
Geothremal	3.5	0.2	7.0	0.2	2
Photovoltaics	0.03	-	3	0.1	100
RE total	**337**	**14.3**	**675**	**23.5**	**2**

Source: http://re.jrc.ec.europa.eu/pvgis/restat/restat.htm#PV%20power

Green Paper: According to the Green Paper of 2000 COM(2000) 769 "Towards a European strategy for the security of energy supply", the main goal was set to be the secure supply of energy to all consumers with accessible cost but with simultaneous protection of environment and promotion of benign competition in European energy market. The importance of the latter has been marked to be significant, particularly because of the Kyoto protocol of 1997 which covered climate change topics and enhanced the importance of environmental dimension and sustainable development, as far as the energy policy is concerned. The starting points for the suggestion were that the EU external energy dependence was constantly increasing. The EU met 50% of its energy needs through imports and, if no action was taken, this would increase to 70% by 2030. This external dependence involves economic, social, ecological and physical risks for the EU. Energy imports accounted then (2000) for 6% of total imports and, in geopolitical terms, 45% of oil imports came from the Middle East and 40% of natural gas imports came from Russia. The EU did not have all the necessary means to change the international market and this weakness was highlighted by the sharp rise in oil prices at the end of 2000.

Towards that objective, the European Council of Lisbon 2000 stressed the need for acceleration of openness of energy markets and in March of 2001 the Commission approved measures that aimed at the complete openness of electricity and natural gas markets, starting from July 2007.

Energy production from RES plays a crucial role in differentiation and sustainability of energy sources, contributing also to the fight against the climate change. Altener, a program created in 1999-2002, institutionalized in 1993, and renewed in 1998, aimed at the promotion of RES by EU.

The latest relevant paper is the directive P6_TA-PROV (2008)0609, with the title "promotion of the use of energy from renewable sources". It is mainly a legislative resolution of 17 December 2008 on the proposal for a directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources. In this paper, improvement of energy efficiency continues to be a key objective of the EU, aiming to achieve a 20% improvement in energy efficiency by 2020. It is stated that energy efficiency and energy saving policies will be for each member-state among the most effective methods in order to increase the percentage share of energy from renewable sources, and therefore more easily achieve the energy renewable sources targets laid down by this Directive, both the overall national target and the transport target. Each member-state should assess, when evaluating its expected final energy consumption in its renewable action plan, the contribution which energy efficiency and energy saving measures can make in order to achieve its national targets as determined in the same paper. Among the countries, Greece is detected to have as target a 6.9% share of energy from renewable sources in gross final consumption of energy in 2005 and 18% in 2020.

Apart from the general directives that promote RES, it is worth mentioning the different policies and incentives that promote PV investments in EU and around the world, and direct the investors and residents to RES. The latter helps us understand what already exists in other countries; the goal and incentives, combined with the results of PVs growth in each country, can give a comparative image of the evolution of PVs market growth in Greece.

Table 3.4: Goals and incentives for the promotion of RES energy production across several countries (2000-2004)

Country	Goal	Incentives
	EUROPE	
Austria	4% of electricity sold derived from RES (2007)	KWh support(0.47-0.60€/kWh), 13 years warrantee, tax deductibility to investors of PVs
U.K.	70,000 rooftop PVs	Support over purchase and installation (40-65% total value)
France		KWh support (0,15-0,3€/kWh), 20 years warrantee
Germany	1,000MW	KWh support (0,457€/kWh). 20 years warrantee, low borrowing rates for PV purchasing
Switzerland		Several applications for each Canton(KW support of 0,6€/kWh, Solar Energy market)
Spain	135MW by 2010	KWh support (0.2-0.4€/kWh), support over the purchase and installation(30-35% total value)
Italy	10,000 rooftop PVs (50MW)	Purchase and installation support (70% total value)
Luxemburg		KWh support (0.45-0.55€/kWh), 20 years warrantee
Netherlands	300MW by 2010 1,400MW by 2020	Purchase and installation support(30-70% of total value averaging at 55%), sales price of 0,068€/kWh
	OTHER COUNTRIES	

Australia		Purchase and installation support(50% of total value): program sponsored by taxation of diesel
U.S.A	1 million rooftop PVs	Tax deductibility(10%) over commercial applications, support of 4,500$/KW or 50% of total value(California), Net-metering (compensation of sold and purchased kWh)
Japan	5,000 MW by 2010	Purchase and Installation Support (50% at the beginning and constantly falling as PVs cost was falling, too).Commercial buildings: 2/3 of system value support, tax incentives, Net-metering, Green Energy Funds

Source: http://www.helapco.gr/library/Strategy%20report%20Feb2003.pdf

Different targets and several policies are illustrated in table 3.4. As far as the particular data is concerned, we may spot some interesting points. Germany seems to promote dynamically the exploitation of RES, as it poses impressive goals (10,000MW from RES) and we recall that it is among the three countries that cover the 68% of the global market share of PVs. The same happens also with Japan, which has been for years the leader of the PVs market and the latter is illustrated by the policies that aim at the goal of 5,000MW by 2010.

The policies may change from year to year in the countries with targets towards RES development. In order to understand the incentives and efficiency of the reported policies for the promotion of PVs, it is more convenient to provide an outline and evaluation of the most important policies. The two most important groups of policies are the normative measures and the measures with voluntary base. Each group is separated in sub-categories, depending on whether each policy aims at a particular target or at the support of investments. We mention the most important:

Normative strategies for PVs support

Investment support: The most important policies adopted in this category are the direct supportive sponsorship of the purchase and implementation of PVs and the tax deduction which aim at the reduced final consumer price.

Tariffication of KWh: The particular measure concerns the grid-connected PVs systems and can be seen in 3 versions; first, we have the FIT according to which the "solar" KWh that is disposed at the network is purchased by the administrator of the network in a "reasonable" price, which is lower than the one that the consumer buys at low-voltage. The settled price is warranted for a long period of time (10-20 years). The second version is the so-called net metering, meaning the compensation of the input to the network and output of the network, KWh. The solar electricity producer sells the surplus of electricity at the price that he/she buys from the electricity company. Finally the third version of tariffication of KWh is the premium prices or the rate-based incentives that reflect the real costs of solar electricity production and is used mostly for small-scale residential PVs applications.

Obligatory minimum solar electricity share: The suppliers of solar electricity are obliged to provide solar electricity at the networks of the country (as a percentage of the total electricity share that can provide), either by producing it themselves or by buying by other producers. The "green commercial certificates" are accompanying the measure, by verifying that a percentage of the electricity produced is generated with the use of PVs.

Voluntary strategies for PVs support

Participative programs: an approach that is mainly adopted in Germany and concerns the voluntary participation of energy-sensitive consumers in solar energy investment projects, by buying assets, by sponsoring relevant public projects (i.e. "solar schools"), or by participating in "moral" funds that aim at environmentally friendly projects (i.e. UK "Wind fund").

Green tariffication: the consumers are willing to buy "green" or in our case solar electricity in higher prices and they obtain the corresponding certificates (i.e. green certificates or the solar stock market that is adopted in Zurich and aim at the warrantee of the derivation of electricity consumed).

The relevant literature has spotted the basic points of each one of the basic policies that aim at the promotion of PVs (Haas, 2001). We tried to summarize the main points of each policy in table 3.5, as an overall evaluation of the strategies for the promotion of PVs.

Table 3.5: Evaluation of the strategies for the promotion of PVs

Strategy	Efficiency of technological promotion	Managerial Interference	Economic efficiency	Promotion of competitiveness
Strategy: Normative and orientated towards the investment cost				
Direct investment support	High	Medium	Medium	No
KWh support	High	Low	Medium	No
Strategy: Normative and orientated towards the installed capacity				
Green commercial certificates	Depends on the % of PVs participation	Medium	High	Yes
Strategy: Voluntary and orientated towards the investment cost				
Green tariffication	Low	Medium	High	Yes
Strategy: Normative with indirect results				
Environmental tariffication(i.e. energy taxes)	Low	Low	High	Yes

Source: Haas R. (2001), Review Report on Promotion Strategies for Electricity from Renewable Energy Sources in EU countries

3.1.6 Policies and measures for PV investment projects in Greece: the changes

After one long period of searches, reports, organizational steps in European and national level, Greece starts creating gradually a free electricity market; the latter will allow clients to choose their supplier and will give the opportunity to new producers to compete with the Public Power Corporation S.A.(PPC S.A.), the only provider of electricity in Greece until recently. The change is considered to be radical for the country, as there is no similar experience from past deregulation of markets of such a size as the electricity market. For the moment, the electricity generation projects by individual investors may provide the PPC S.A.

Law 2773/99, RAE (Regulatory Authority for Energy) and HTSO ("the Operator")

The basic law governing RES is Law 2773/99 "Liberalization of the Electricity Market – Regulation of Energy Policy Issues and other Provisions," (Chapter 10, Articles 35-41). This law has incorporated the majority of provisions of the earlier Law 2244/94, which was devoted entirely to RES matters. According to this law, the two companies - the Regulatory Authority of Energy (RAE) and the Hellenic Transmission System Operator (HTSO S.A. or "the Operator") have been created. These two companies are the basic factors of the free electricity market.

RAE is an independent, public authority that manages, suggests and promotes the existence of equal opportunities and fair competition. It gives operation licenses to producers, providers, and all others related to the market. In addition, RAE formulates suggestions to the Minister of Development with regard to the issue of power generation authorizations. Thereafter, RAE monitors the implementation progress of the renewable energy sources (RES) projects through quarterly reports and recommendations, which can recommend that investors remove from the sector due to unjustifiable slowness. RAE also recommends legislative measures for further deregulation of the electricity market within which critical RES issues can be addressed (as is the case of hybrid plants). On a more long-term basis, RAE considers the introduction of green certificates and the establishment of a network of large scale dispersed energy production.

HTSO S.A. is a company with a double role:

The first role is the one being played by P.P.C. in respect to the transmission system: it always looks after for the existence of a balance between production and consumption and the electric energy to be provided in a reliable, safe and in terms of quality acceptable way.

The second role of HTSO is to settle the market, in other words to act like an energy stock market that arranges on a daily basis who owns to whom. HTSO does not provide electric energy and whatever basic exchanging relations exist they are bilateral ones between producers/providers and their customers.

Therefore, P.P.C S.A. will constitute one among a number of companies that will be created in the field of electric energy. A stock market pictorial description of the roles could be, P.P.C. is an admitted company, HTSO is the Stock Market and RAE is the Capital Market Committee.

The key provisions of Law 2773/99 are:

- The Transmission System Operator (HTSO) is obligated to priority access to RES projects.
- The HTSO is obligated for a 10-year contract (PPA) with the producer including a renewal option.
- The RES electricity production is sold to the HTSO at a predetermined buy-back rate.
- The current RES electricity tariffication system distinguishes between “auto-producers” and “independent power producers”.
- Every RES electricity producer is subject to a special annual fee (2% of the producer’s electricity sales to the grid), which will be given to the local authority.

Law 2773/99 instituted a new license, the so-called electricity generation license, which is now the first license required to be obtained by any electricity-producing station, conventional or RES-based, in a long planning/licensing procedure that also includes preliminary environmental assessment, land-use permit, approval of environmental terms and conditions, installation license, operation license, etc.

Law 2941/01 supplemented Law 2773/99 with certain important provisions including: a) the definition of the general terms and conditions, under which it is allowed to install RES stations in forests and forestry lands, and b) the characterization of all RES projects as projects of public utility status, which give them the same rights and privileges in land expropriation procedures as those given to public works, independently of the legal status of the RES project owner (being private or public).

Law 3468/2006, the fixed feed-in tariff schedule

The incentive scheme that was established in Greece in 2006 included, apart from priority in the dispatch and an investment subsidy of [30%-60%] according the investment incentive law, a FIT for purchasing the electricity generated by PV systems. The PVS FITs were set at levels 5 – 6 times higher than the corresponding on-shore wind and hydro FITs (Table 3.6). In order to make the grid restrictions explicit, but also to control the overall cost for the consumers, the national RES implementation program set an upper limit on the PVS capacity per administrative region. The relevant law that started a sequel of changing policies was law 3468/2006, with the title “Generation of Electricity, using Renewable Energy Sources and High-Efficiency Cogeneration of Electricity and Heat and Miscellaneous Provisions”. The particular law made several radical changes:

- Identified new simplified licensing procedures
- Settled sales prices of electricity produced with the use of RES, giving incentives in relevant investments (particularly beneficial terms for PV arrays system)
- Sets the investment goal of implementation of PV power systems, 500 MW for continental Greece and 200MW for the islands
- The guaranteed market price is increased up to five-fold (for the PV systems)
- The market time expands from 10 to 20 years
- The licensing deadlines were being significantly reduced

The law aims to act as the tool for achieving the national target for 20.1% production of electricity from RES until 2010 and 29%, until 2020.

Table 3.6: The 2006 feed-in tariffs schedule (€/MWh)

Energy source	Interconnected system	Non-interconnected islands
Small PV (<= 100 kWe)	450	500
Large PV (> 100 kWe)	400	450
Small non-PV solar (<= 5 MWe)	250	270
Large non-PV solar (> 5 MWe)	230	250
Off-shore wind	90	90
Other RES (on-shore wind, small hydro, geothermal, biomass, etc.)	73	84.6

Source: Hellenic Republic. Law 3468/2006, Electricity generation form RES, combined heat and power generation and other provisions. FEK 129, June 27th 2006.

Particularly for PV power plants, the law is highly beneficial, as the settled sales electricity prices are higher than other sources, reaching 0.45€/kWh for the grid connected system (continental Greece) and 0.50€/kWh for the non-grid connected islands. The beneficial regulation created problems with bureaucracy and the licensing authorities were not in a position to cope with the thousands of applications that were received.

Law 3734/2009, the de-escalating feed-in tariff schedule

The deficiency of the 2006 incentive scheme, coupled with the administrative burden of the rather bureaucratic licensing procedure, explains the still low level of PVs penetration in Greece, compared with other European Union countries with similar climatic conditions. By the end of 2008, the total installed photovoltaic capacity in Greece was equal to only 9.3 MW, out of which 8.7 MW were connected to the grid. This represents a mere 0.2% of the total PV systems capacity in the EU-27 group, which amounts to 4,592 MW.

In the light of these new developments, a new scheme was voted for in January 2009, 3734/2009, with the title "Promotion of cogeneration of two or more useful forms of energy and miscellaneous other provisions". The capacity limits were scrapped. Granting licenses to all applicants would have led to a large increase in the retail price of electricity and to a fuel mix that would not have been optimal, even if all external environmental costs were taken into account. In order to moderate the burden on the final consumer from the PVS program, the FIT in Greece was set to gradually de-escalate.

Table 3.7: The electricity sales prices according to law 3734/2009, in Euros per MWh

Year	Month	A	B	C	D
		Interconnected System		Non-Interconnected Islands	
		> 100kW	<= 100kW	> 100kW	<= 100kW
2009	February	400,00	450,00	450,00	500,00
	August	400,00	450,00	450,00	500,00
2010	February	400,00	450,00	450,00	500,00
	August	392,04	441,05	441,05	490,05
2011	February	372,83	419,43	419,43	466,03
	August	351,01	394,88	394,88	438,76
2012	February	333,81	375,53	375,53	417,26
	August	314,27	353,56	353,56	392,84
2013	February	298,87	336,23	336,23	373,59
	August	281,38	316,55	316,55	351,72
2014	February	268,94	302,56	302,56	336,18
	August	260,97	293,59	293,59	326,22
For each year n, from 2015 onwards		1,3 x SMP_{n-1}	1,4 x SMP_{n-1}	1,4 x SMP_{n-1}	1,5 x SMP_{n-1}
SMP_{n-1}:	*Average System Marginal Price for the previous year n-1*				

Source: http://www.renewable-energy-sources.com/2009/10/21/renewable-energy-prices-in-greece/

The prices defined in the above table, in Euro per MWh, shall be adjusted each year, at 25% of the consumer price index (so as to express the revenues growth rate or inflation rate) of the previous year, as established by the Bank of Greece. If the PV electricity price, thus indexed, is lower than the average System Marginal Price (SMP) of the previous year as measured by HTSO, increased by 30%, 40%, 40% and 50%, respectively, for the cases A, B, C and D of the above table, then the pricing shall be done on the basis of the average SMP of the previous year, increased by the corresponding factors (i.e. by 30, 40, 40 or 50%). SMP is measured by HTSO for each hour of the day.

In their paper, Danchev S., Maniatis G., Tsakanikas A. (2009), find that the particular scheme favors strongly the early entry in the market. Entering the market from 2015 onwards will be prohibitive, unless there is a significant decrease in the equipment cost over the next decade. However, they stress the fact that the bias of the particular policy design towards early entry in a rapidly developing set of technologies entails the risk of a lock-up with sub-optimal technological option. The latter outlines the importance for policy design of linking the rate of FIT de-escalation to more realistic expectations regarding the technology learning curve. In the present paper, we will also try to shed light at the particular parameter of the policy, in chapter 5.

The particular legal framework contains a provision that the authorities may change the FIT de-escalation path depending on the technology's penetration levels and the consumer cost.

Law 3851/2010: Updated changes of de-escalating feed-in tariff policy for PVs

In May 2010, the Greek legal framework supporting the electricity producing photovoltaic systems (PVS) changed again; after the change of January 2009 from a fixed to a de-escalating FIT schedule some additional measures are now incorporated. The current framework for the present potential investors includes the updated policy 3734/2009 and the exclusion from the national investment incentive law 3299/2004 (from January 2010) which provided 40% subsidy grant of the investment cost. The new investment incentive law is expected to be voted in September-October; however there is a possible scenario that the PVs investment projects will not have the right to be subsidized, due to the impressive noted reductions in costs.

The logic behind the current legal framework is quite the same as the previous one. We spotted some basic differences though:

1. A new goal is set as far as the electricity production with the use of RES is concerned; 40% of the total production capacity should be with the use of RES by 2020
2. Article 3, paragraph 1z changes the criterion of economic sufficiency of the potential investor; the potential investor does not need to own all the economic resources to implement the project, but he should have the capability to assure the financing of the investment from his

own equity, capital structure with leverage, funds, or each legal way he prefers, cooperating with financial institutions.

3. There are new specifications that ease the licensing for the implementation of PV power stations, and more particularly stations of up to 1 MW; i.e. an additional easing provision is that the new law excludes the necessity of environmental reports for this category of projects, but a simple certification instead. As already mentioned the bureaucratic delays constituted the main disruptive factor for new investments in the sector until now. The paradox situation of lagging behind on the path to meeting the RES targets and refusing to grant licenses to thousands MW of PVS capacity led to the need for a radical restructuring of the incentive scheme.
4. The PV power projects of capacity up to 0.5 MW simply have to assure the sales contract with HTSO, avoiding major problems with bureaucratic procedures. Moreover, the updated policy provides the right to an individual investor to own more than one project (limits in the distance from one to another) without having to follow the application procedures for all of them, but only once.
5. There are implications that the licensing provided by the RAE will be opening gradually, depending on the need of each municipality, or after the decision of the corresponding Minister over the expected analogy of technology and its distribution in time. Priority is given to the applications not yet examined or approved due to the recent license-freeze. An easing exemption is given to farmers for projects up to 100KWp in their own private land.
6. As for the electricity sales prices, they remained the same as determined in law 3734/2009 (Table 3.7). The tariffs are initially set at 400, 450 or 500 €/MWh depending on the PVS's size (larger or smaller than 100kW) and location (interconnected system or non-interconnected islands). Starting from August 2010, the tariffs de-escalate every 6 months to reach 260.97 – 326.22 €/MWh for the period August – December 2014. This amounts to an accumulated reduction of 35% over the period of 6 years or 6.9% compounded annual reduction rate. From January of 2015, the FITs will be set to the previous year's average price in the wholesale electricity market plus a premium that varies between 30% and 50% depending on the PVS's size and location. The PVs with capacity lower than 100 kW and those that are installed in the non-interconnected islands are paid higher FITs both before and after January 2015. The FIT schedule is updated each year, taking into consideration the inflation rate. The compensation is not full, however, but amounts only to 25% of inflation. The rationale of the *x * CPI* –rule is that the less than full compensation provides incentives for constantly improving the efficiency of

the subsidized unit through innovation, learning, and so on. In the case of PVS, where the disproportionately higher percentage of the cost to the PVS operator comes from the investment expenditure, made prior to the beginning of operation, the adoption of this rule is not adequately justified. Setting the compensation parameter at such low levels actually implies a second-order de-escalation effect.

The prices, as defined by the updates in the policy, are presented in Table 5.3 in chapter 5.

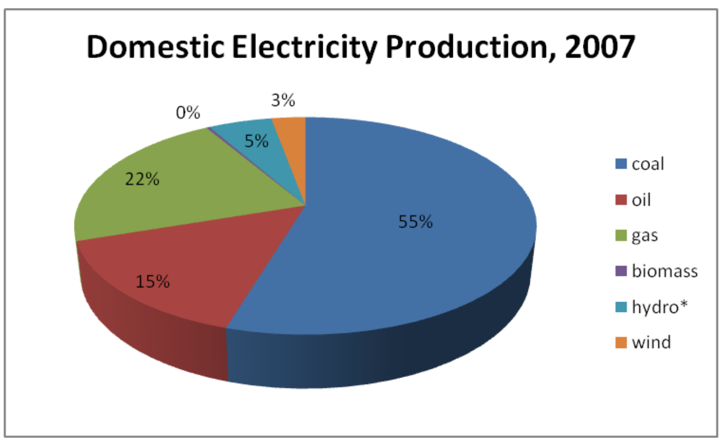
As far as the sales prices are concerned, the major difference of the updated policy concerns the tariffication of the non-interconnected islands, which can sell electricity at one price depending only on the year and not the capacity installed.

3.2 Electricity: Domestic Data

3.2.1 Domestic Electricity Production

According to IEA, the domestic electricity capacity for the year 2007 is presented in the figure below:

Figure 3.8: Domestic Electricity production, in GWh (2007)

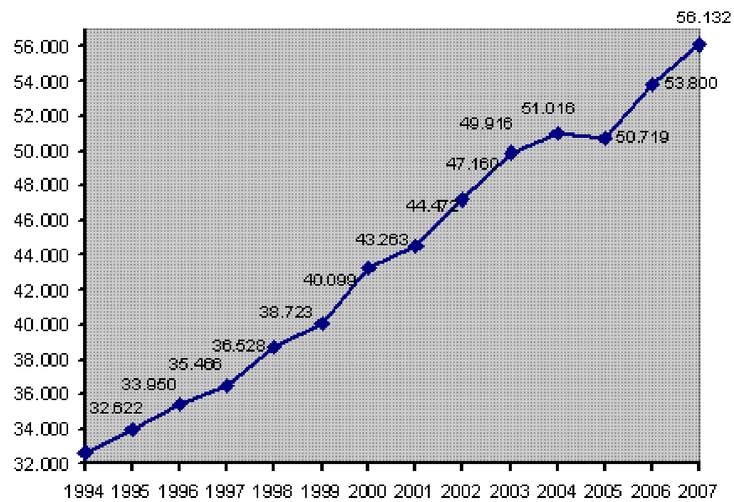


Source: http://www.iea.org/stats/

As easily observed and already mentioned, coal is the main source used to produce electricity in the country and the natural gas follows. As far as the RES is concerned, hydroelectricity covers the 5% of the total production and wind power 3%. Solar energy is not present in the electricity production map of the country and we may comment that only a small share (8%) of total electricity capacity is produced with the use of the so-called environmentally "friendly" sources (hydro and wind).

The historical evolution of the electricity production in Greece is presented in the figure 3.8. We provide the figure in order to follow the levels of electricity produced by PPC S.A. in the country and we may notice that from 1994 to 2007, the electricity capacity produced has increased by around 72%; the percentage of growth is striking and reflects the demand from the side of consumers.

Figure 3.9: Historical evolution of electricity production in Greece (1994-2007)



Source: http://www.dei.gr/ECPage.aspx?id=2610&nt=101&lang=1

According to the data presented in the section, the participation of PVs in electricity production until 2007 does not practically exist; the latter could be explained by the increased cost per watt of PVs technology, and the barriers built by the laws before 3468/06.

3.2.2 Electricity: Imports and Exports

The Greek grid-connected electricity system is connected through transportation lines with the countries below:

Albania, via a line of 150KV and a second of 400KV

FYROM, via a line of 150KV and a line of 400KV

Bulgaria, via a line of 400KV

Italy, via a subsea wire of 400KV

The total power transmission capacity of all the international interconnections of the Greek transmission system is shown in table 3.9.

Table 3.8: Power Transmission Capacity of the International Interconnections of the Greek Transmission System (MW)

Interconnection	From Greece	To Greece
Greece-Fyrom	500	1,000
Greece-Albania	250	
Greece-Bulgaria	400	
Greece-Italy	500	500
Total	**1,650**	**1,500**

Source: Energy Outlook of Greece, Ministry of Development, Hellenic Republic, February 2009

It is interesting to stress the structure of the Greek energy balance though. According to IEA, in the year 2007 there were electricity imports of 6,446 GWh and exports of 2,071 GWh, leading to a negative balance of.4,375 GWh. The data are quite impressive when considering that the capacity of interconnections allow exporting more than importing energy. The deficit in energy and electricity balance is a huge issue that should be taken into consideration; when considering a negative energy balance is combined with the goals of Green Paper of 2000 over the supply security, the favorable conditions of the current law, the amount of money for the purchase of imported fuels, and the increasing demand, the promotion of "green" energy generation and distributed production is more than necessary. The effort is already visible with the changes in legal framework and the trends seem favorable for RES not only due to the promotion policies but according to the trade conditions, too.

For the near future, the upgrading of the connections with Turkey and Bulgaria is being studied. More particularly, in November 2008, Greece and Bulgaria signed an agreement for the construction of the second electricity transmission interconnection line which will contribute to the balance and security of the country's electricity system. Moreover, in June 2008 a Protocol for Cooperation was signed between Greece and Turkey for the exchange of electricity with a capacity of up to 200 MW to cover peak loads in the two countries.

The electricity trade balance is projected to remain with deficit at least for the next few years, which in turn means that there will definitely constitute necessity to increase the electricity production; there is room for remote small or even big scale projects that can ensure the secure electricity distribution. The latter is reinforced also by the fact that the estimations show higher dependence on imported fuels (natural gas and oil). The data are taken by the National Plan of emission rights for the period 2008-2012, published by the related ministry and delivered in European Commission in September of 2006, which have projections of the national energy trade balance.

3.2.3 Electricity: Demand and Consumption

The electricity consumption levels are presented in the table below:

Table 3.9: Consumption electricity levels World, Europe, Greece, 2007

	World		Europe (27)		Greece	
Consumption of	**GWh**	**%**	**GWh**	**%**	**GWh**	**%**
Industry	6,939,676	42%	1,149,931	40%	15,328	28%
Transport	270,210	2%	72,927	3%	251	0%
Residential	4,472,948	27%	801,047	28%	17,957	33%
Commercial and Public services	3,832,314	23%	759,050	27%	18,773	34%
Agriculture/Forestry	421,885	3%	51,271	2%	2,881	5%
Fishing	4,094	0%	269	0%	0	0%
Other	504,602	3%	5,282	0%	0	0%
Total Final Consumption	**16,445,729**		**2,839,777**		**55,190**	

Source: http://www.iea.org/stats/

First of all, focusing on Greece we could mention that there has been an increase of around 11%, when compared to levels of 2005 (49,719 GWh), indicating an annual increase of around 4% to 5% (2005-49,7GWh, 2006-53,5GWh, 2007-55,19GWh).

Even though the global and European levels of electricity consumption come mainly from the industrial sector with the percentage of around 40%, in Greece commercial and public services have the largest share of 34%, residential consumption follows with 33% and industry is the third source with 28% of total electricity consumption.

The annual electricity consumption of 2007 in GWh per resident showed 5.6 for the average Greek resident, 6.2 for the average European, 13.6 for the average resident of USA, and 2,7 for the world average resident (IEA key statistics, 2007). We can comment that although Greece has relatively low electricity consumption in industrial sector, the levels of electricity consumption do not deviate correspondingly from the ones of Europe.

According to the data of the PPC S.A., the annual electricity consumption per resident in Greece followed the historical evolution as presented in the table 3.11. The increasing annual levels per resident exhibit the real growth in demand, apart from the population growth, as the year pass.

Table 3.10: Annual consumption per KWh/resident throughout the years

1950	1960	1970	1980	1990	2000	**2006**	2007
88	**265**	**976**	**2,106**	**2,923**	**4,113**	**4,883**	**4,970**

Source: http://www.dei.gr/ECPage.aspx?id=2610&nt=101&lang=1

An issue that concerns demand and distribution, and should be taken into account for Greece is the problem of secure electricity production and distribution, which is worsening by the fact that the electricity system in Greece is regionally unbalanced; the largest share of installed capacity is situated at North Greece, whereas the most important centers of consumption are situated at South Greece; the sources are best exploited in North Greece but the biggest urban center of Athens, which covers half the population of the country, is situated in the south of the country. We can understand that the latter may cause serious problems of secure supply; small-scale distributed projects can constitute a feasible solution.

3.3 Existent Competition

The main electricity producer in Greece is the PPC S.A. PPC owns 93% of the installed power capacity in Greece, generated by lignite, fuel oil, hydroelectric and natural gas power plants, as well as by aeolic and solar energy parks. It owns 99.7% of the Greek electricity market and it is the largest business in Greece in terms of assets. In 2007 the Company recorded revenues amounting to 5.15 million Euros and pre-tax profits amounting to 276 million Euros. Total electrical power is generated by the 98 PPC power plants, is transmitted via 11,750 km high voltage lines and distributed to consumers via a 214,000 km-long network. The installed capacity of PPC is illustrated in the table below:

Table 3.11: Annual installed capacity (MW) of the Public Power Capacity S.A.

1950	1960	1970	1980	1990	2000	2006
80	**605**	**2,578**	**5,407**	**8,812**	**11,121**	**12,695**

Source: http://www.dei.gr/ECPage.aspx?id=2610&nt=101&lang=2

As for the electricity production from PVs, there is no competition as the law 3468/06 determines the provision of licenses from RAE, under the conditions that there is sufficient demand and network connection infrastructure. Moreover, the law provides priority to electricity consumption from RES; the sale of all the amount of electricity produced from PVs to the national network is assured.

Law 3468/06 defines the sale contract in Article 12, which is valid after all the policy changes up to date:

1. For the connection of electrical power generation plants using RES or through high-efficiency cogeneration to the System or the Network, including the Network of the islands not connected to the mainland's interconnected System according to articles 9 and 10 hereof, the System Operator should, in case the power plants shall be connected to the System either directly or through the Network, or the Operator of the islands not connected to the mainland's interconnected System, in case the power plants are connected to the Network of the islands not connected to the mainland's interconnected System, conclude *an electricity sale contract* with the holder of the relevant production authorization.

2. The sale contract for electricity produced in hybrid stations is valid for *twenty (20) years* and may be extended according to the terms of the relevant production authorization upon a written agreement by the parties, provided that the production authorization is still valid.

3.4 International market-Prices

As widely known, the oil industry uses price per barrel as its unit of price measurement. In the present paper we mentioned several times the Wp; the solar energy industry typically uses price per Watt Peak (Wp) as its primary unit of measurement. The prices for high power band (>125 watts) solar modules has dropped from around $27/Wp in 1982 to around $4/Wp today. Prices higher and lower than this are usually dependent upon the size of the order.

On a general approach of solar electricity prices today, they move around 30 cents/kWh in the most important markets. This precise calculation will depend evidently on the location of the solar installation and the local electricity tariff rates. Then in order to determine what proportion of total energy solar will provide, one has to take in to account the size of the solar energy system and the energy demand of the customer.

Around 59% of world solar product sales installed the last five years were in applications that are tied to the electricity grid. Solar energy prices in these applications are 5-20 times more expensive than the cheapest source of conventional electricity generation, although they may only be 3-5 times the electricity tariff that utility customers pay. By contrast, PV can be fully cost competitive on economic grounds in remote (off-grid) industrial and residential applications.

In order to illustrate a general image of the international electricity prices derived from PVs, we used the solar electricity index below. It draws exclusively upon the global Solar Module prices in our survey in the high power band exclusively (> 125 Watts). The index used is based upon a climate with 5.5 hours of sunshine average over the year. This is typical of locations like US Sunbelt States, much of Latin America, most of Africa, the Middle East, India and Australia. Mediterranean Countries, including Greece, followed by Japan and then Northern Europe have progressively lower average hours. Saharan and southern Africa, and the areas centered on Saudi Arabia, central Australia, Peru and Bolivia are higher.

Table 3.12: Commercial Electricity prices, 2010 (Solarbuzz Solar Electricity Index)

Cents per kWh	Commercial Electricity price
January 2010	25.15
February 2010	25.03
March 2010	24.85
April 2010	24.81

Source: Solar Electricity Prices Solarbuzz LLC

Prices have historically been declining at around 4% per annum and this decline is expected to continue over the medium term.

CHAPTER 4 Methodology

The basic steps of the methodology of a financial report analysis concern the framework of Cash Flow Analysis (CF Analysis). In the present paper we choose to build a benchmark model under certain assumptions. The CF analysis uses two basic tools: the Net Present Value (NPV) and the complementary measure of Internal Rate of Return (IRR). With the help of these two measures, we may take the first results over the economic viability of our benchmark model of the PVs project we chose. Moreover, the parameterization of the relevant tables in Microsoft Excel helps us continue with the sensitivity analysis; differentiation of input parameters lead us to the critical values for which the project is financially viable, as well as, to the different alternatives of the project (scenario analysis). The investigation of results using different input parameters may orientate the potential investor towards taking the optimal decisions, when planning the investment project. Finally, we work with supplementary measures of economic viability (ratio analysis and simple payback method) to check the robustness of our results.

4.1 Benchmark model: revision of assumptions

The necessary input for the first step of the methodology is the consideration of all the assumptions we made, so as to conclude with the results of the benchmark model. Summing up the assumptions of chapter 2 and including additional ones, we may mention all the basic points:

1) The investment project concerns a PVs power project in North-Central Greece
2) The economic viability of the investment project is investigated under the recently introduced de-escalating feed-in tariff policy over PVs (Law 3734/2009 and updated changes of Law 3851/2010)
3) The input of the PVs plant is solar energy and the output is electricity, which is directly provided at the national electricity network, without the necessity of being stored
4) The PVs power project consists of 432 panels of multi-crystalline silicon technology of 230 KWp each, resulting in the total capacity of 99.36 KWp
5) The use of the technology of heliostat trackers is included
6) The technical characteristics of the PVs project can result in the provision of 1,711 KWh per installed kWp, according to the official software of PVGIS application
7) The technical characteristics of the PVs power plant result in the initial investment outlay of 451,890 €

8) The system losses are considered to be 0.8% per year (under the assumption of 3% cable losses and about 15% losses in total according to PVGIS software)
9) The capital financing structure of the project can be accomplished with 75% borrowing at 7% interest rate and 25% equity capital
10) The economic valuation period of the investment project is 20 years, covering the long-term goal of at least 20-years existence of the project
11) We may assume that a new company is created for the implementation of the investment project. Taking into account the size of the project and the capital needed, we may assume that a creation of L.P. company is rational to support its implementation

Based on the assumption above, we are able to complete all the necessary tables for the CF analysis.

4.2 Discounted Cash Flows Analysis (DCF Analysis) and IRR

In the present paper we use two main measures for the valuation of the PVs power plant; the Internal Rate of Return (IRR) and the supplementary measure of Net Present Value (NPV).

At this point, we could justify our choice of DCF Analysis as the main methodology to approach the economic viability of the PV power system as investment project. Scanning the relevant literature, we ended up with the static NPV approach because of the project-specific characteristics; it is a long-term project, with a given initial investment cost and certain returns, due to the FIT policy as well as to the long-term sales contract with the HTSO S.A.

It was those specific characteristics that led us to exclude, first of all, the Real Options methodology, which could be actually used for the valuation of a power plant. Options are embedded in power plants and so-called real option valuation methods are applied to valuate investments in the energy sector. There are different models for a power plant valuation under the assumption of the embedded options, but we may exclude them as the development of the investment project is a now-or-never decision, under given cost and returns for the 20 years of the valuation period; therefore, we may reach the conclusion that static NPV Analysis is the most appropriate method.

In terms of analysis, we use certain techniques for capital budgeting which orientate the potential investor to make a decision over the investment project. We may assume that the stream of cash flows provided by the project is estimated without error.

The basic measures of DCF Analysis methodology are the Internal Rate of Return (IRR) and the supplementary measure of Net Present Value (NPV).

Net Present Value (NPV)

Net Present Value (NPV) expresses the present value that a series of cash flows will have in the future. The NPV is calculated by (Copeland, Weston 1992):

$$\text{NPV} = \sum_{t=1}^{n} FCF_t \cdot (1+k)^{-t} - I_0 \qquad (1)$$

Where FCF_t are the Free Cash Flows of the project at year t, k is the discount rate, I_0 are the capital investments of the project and n are the years of the valuation period or the expected lifetime of the project. The NPV criterion accepts projects that have an NPV greater than zero. The formula shows that the NPV is computed by discounting the cash flows at the firm's opportunity cost of capital.

Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) represents the profits and other benefits of the PVs project, expressed in the portion of the annual performance of the initial costs of the project. Summarizing the concept of IRR, we may mention that the IRR of an investment is the interest rate at which the costs of the investment lead to the benefits of the investment. This means that all gains from the investment are inherent to the time value of money and that the investment has a zero net present value at this interest rate; IRR is the rate which equates the present value of the cash outflows and inflows, thus making the computed NPV exactly zero. Mathematically, we solve for the rate of return where the NPV equals zero (Copeland, Weston 1992):

$$\text{NPV} = 0 = \sum_{t=1}^{n} \frac{FCFt}{(1+IRR)^t} - I_0 \qquad (2)$$

Where I_0 is the project's total initial cost, FCF_t are the Free Cash Flows of the project at year t and n are the years of the valuation period or the expected lifetime of the project. The IRR criterion suggests that we accept any project that has an IRR greater than the opportunity cost of capital. As proven by the formula, the NPV and IRR criterion function in a supplementary way.

Brealey RA (1996) states that IRR is a popular investment rule according to which if the IRR of an investment A is higher than that of other feasible alternative investments, where the rates are risk-adjusted to make them comparable, the investment A is considered attractive. However, Dancev et al.

(2010) mention that in the case of PVs, their interaction with other technologies in electricity generation portfolio, might reduce the overall portfolio risk at a cost worth paying. The latter makes the investment in PVs attractive even in the case of a relatively low IRR. Nevertheless, IRR remains an important indicator of an investment's attractiveness and offers an objective and comparable perspective over a project's efficiency; that is the reason why we chose IRR to be the basic measure of economic viability in our estimations.

4.3 Input Parameters

Discount Rate

An important input parameter of the NPV analysis of the investment project is the choice of the discount rate; calculating present values is discounting cash flows. A fair discount rate should reflect the perceived project risk, the inflation, and the time preference. As widely known, if the project has an "average" firm risk, the analysts may use the default benchmark; the most commonly used discount rate is the Weighted Average Cost of Capital (WACC):

$$WACC = w_E\,(r_E) + w_D\,i\,(1-T_C)$$

Where w_E is the weight of equity in total market value, r_E is the cost of equity, w_D is the weight of debt in total market value, i is the cost of debt and T_c is the corporate tax rate.

In case the risk of the project is above or below average, the analysts may adjust the WACC upwards or downwards, correspondingly.

However, we have to consider the project-specific characteristics to decide the optimal discount rate for our estimations. The goal of long-term horizon of the investment project, the low risk of efficiency because of the technology and the FIT policy suggest that the investor can rely highly on the weighted leveraged capital financing. The latter leads us to the argument of using the *cost of debt* as the discount rate for our NPV analysis. We may take into account the computational cost of defining the cost of equity; its calculation needs as input the dividends' growth and the market value of the stock of corresponding company that can take on the project, or equity beta, the market risk premium and the risk-free rate (CAPM). Taking into consideration that the benchmark model does not need the size of a P.L.C. company supporting the specific project, we look at different directions for the choice of the discount rate. Balancing all the elements above, we suggest that NPV analysis discount rate be the cost of debt, meaning the interest rates of the long-term bank loan. In our analysis, the cost of debt may be considered as the opportunity cost of investment.

Nevertheless, we can understand that the discount rate is a choice that contributes to our estimations; the results could be sensitive to the particular choice that is why we include differentiations of the discount rate as input of the model in the sensitivity analysis of chapter 5.

Depreciation/Amortization method of tangible/intangible fixed assets

The valuation period of the investment project is 20 years and a choice of depreciation method for the tangible fixed assets and amortization for the intangible fixed assets is needed. A reasonable choice for the particular investment project is the *straight-line* depreciation method. According to the straight line depreciation method, the coefficients of depreciation are calculated using the years determined by the existent accounting framework for each category of tangibles/intangibles. In general, the accounting framework determines 5% minimum coefficient and 7% maximum coefficient for PVs projects depreciation. We choose that the depreciation of the parts be in 15 years, meaning a depreciation coefficient of 7%. It is worth mentioning that in case a future user of the MS Excel tables prefers shorter or longer period of depreciation for the project, the changes are easily applicable without affecting the results; simply changing the years of depreciation for each category leads to the corresponding final results due to full parameterization of the tables.

General and Administrative Expenses and Costs of Goods Sold

The determination of the particular category of expenses is ambiguous in terms of capital budgeting and a choice has to be made; the relevant research showed that a reasonable percentage is 1.3% of the estimated revenues.

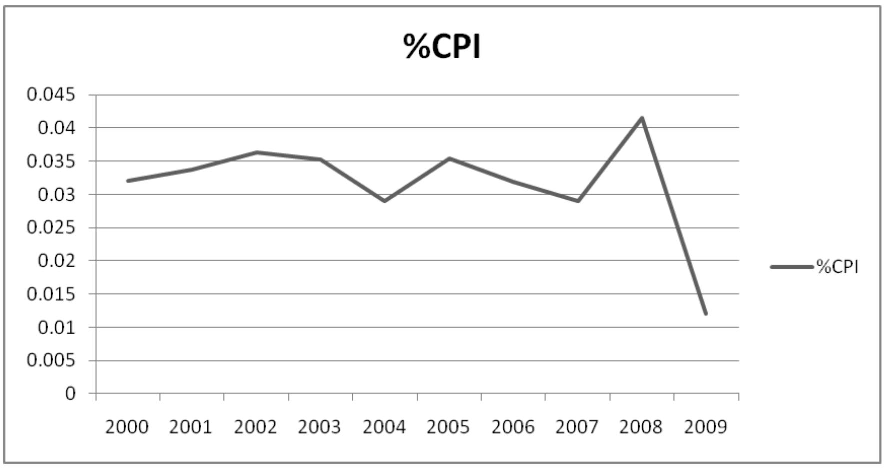
As for the costs analysis of the annual costs of goods sold (insurance, security and maintenance of technology, cleaning and other maintenance costs), the notes of Table 2 in Appendix clarify the choices that have been made.

Consumer Price Index (CPI)

As analyzed in section 3.1.6, the prices as defined by the FIT framework, shall be adjusted each year, at 25% of the CPI (so as to express the revenues growth rate or inflation rate) of the previous year, as established by the Bank of Greece. CPI is therefore an important input parameter so as to determine the level of sales prices, thus the level of revenues, of the investment project. Evidently, there cannot be accurate forecasts of the annual average of each year's CPI for the next 20 years; a choice has to be made.

Focusing on the data given by the Central Bank of Greece, the %CPI of the last 10 years fluctuated as illustrated in the figure below:

Figure 4.1: The %CPI of Greece from 2000-2009 (base year=2005)



Source: http://www.bankofgreece.gr/Pages/en/Statistics/default.aspx

We cannot ignore the steep reduction of the index from the middle of 2008, which is apparently due to the effects of the financial crisis. The %CPI of the last years indicates that a safe scenario for the next 20 years could be an average of *2%*; therefore we may assume that an acceptable level of reference for the revenue's growth is around 2%, which is used to determine the level of electricity sales prices for the next 20 years of the valuation period.

4.4 Robustness of results

Ratio Analysis

Profitability index

The profitability index, PI, represents the comparison between the project's NPV with the capital investment of it, I_0. Positive values of this index show a good economic performance of a project.

Gross Margin

The gross margin represents the percent of total sales revenue that the company retains after incurring the direct costs associated with producing the goods and services sold by a company. It is calculated by the formula:

$$\text{Gross Margin (\%)} = \frac{\text{Revenue} - \text{Cost of Goods Sold}}{\text{Revenue}} \quad (3)$$

The higher the percentage, the more the company retains on each Euro of sales to service its other costs and obligations. As we can understand, high percentages of Gross Margin are positive for the company that supports the investment project.

Operating Margin

In general, operating margin is a measure that shows how well a company controls its costs; a measure of the company's pricing strategy and operating efficiency. It is calculated by the formula:

$$\text{Operating Margin} = \frac{\text{EBIT}}{\text{Sales}} \quad (4)$$

A healthy operating margin is required for a company to be able to pay for its fixed costs, such as interest on debt.

Simple payback

The payback period for a project is simply the number of years it takes to recover the initial cash outlay on a project. If management were adhering strictly to the payback method, it would prefer that the project have the shortest possible payback period; a casual inspection of the cash flows shows that this is clearly wrong. The difficulty with the payback method is that it does not consider all cash flows and it fails to discount them. Although we include the payback method, we should be very careful because it violates an important property that is desirable in capital budgeting techniques; the discounting at opportunity cost of capital. Moreover, the payback method does not account for savings that may continue from a project after the initial investment is paid back from the profits of the project, but this method is helpful for a "first-cut" analysis of a project.

4.5 Sensitivity Analysis and Scenario Analysis

Sensitivity analysis is a technique used to determine how different values of an independent variable (input cost, de-escalated prices, production capacity levels, technology, (no)/use of trackers, financial parameters) will impact a particular dependent variable (IRR) under a given set of assumptions. In combination with the capital budgeting methodology that we follow in the present paper, sensitivity analysis determines the different choices that are available to the potential investor. Finding the critical values for which the project is economically efficient or illustrating the evolution of project's IRR for different input parameters gives intuition over the project's viability.

After investigating the sensitivity of the model to different input parameters, we choose to extent the analysis of the results following the scenario analysis method; the best and worst case scenario show the importance of the choices and the market research that the investor should make.

CHAPTER 5 Results

The implementation of the methodology, analyzed in chapter 4, gave as output certain interesting results. In this chapter we attempt to present, explain and group the results of the estimations of capital budgeting, so as to give a complete image of the project's significant parameters for the purposes of financial analysis.

5.1 Initial Parameters

The first step, before continuing with the basic results, is to resume all the initial parameters needed for the estimations. As already explained, all the tables of estimations that result in the final critical measures of financial viability are fully parameterized according to certain initial parameters, meaning everything that our model needs as input to lead to the specific output. Any change of the initial parameters of the model means different results.

Benchmark model: the basic assumptions

Table 5.1: Benchmark model: the basic assumptions

Type	Multi-crystalline sillicon technology	
Amount	*432*	PV panels
Nominal power (each)	*230*	kWp
Total nominal power	*99.36*	KWp
Expected production		
per kWp	*1,711*	kWh
per year	*170,000*	kWh
Total system energy losses	*0.8%*	per year
Total capacity	*1,711*	KWh/KWp
Total initial investment cost	*451,890*	Euros

Financial Parameters

Capital Financing of the Investment Project

Equity = 25% Borrowing = 75%

Borrowing conditions

Table 5.2: Benchmark model: borrowing conditions

Interest rates	**7.00%**	
Loan duration	10	years
tranches/year	2	
number of semi-annual tranches	20	

L.P. form of company

Tax rate = 20% Payable Dividends = 0

Production Process Parameters

The parameters that concern the production process are presented in Table 1 of the Appendix for the 20 years of the valuation period. No scaled production is predicted and the process starts from the 100% of its potential from the first day of operations. The capacity level in normal function is 170,000 kWh per year. However, we should not ignore the fact that system losses should be incorporated (assumption of 0.8% per year); therefore even if the production capacity level starts from 170,000 kWh in year 1, it ends up about 146,000 in year 20.

Sales prices Parameters

Table 5.3: Benchmark Model: Sales prices according to L. 3851/2010

prices in Euros per MWh

		A	B	C
		Interconnected System		**Non-Interconnected Islands**
Year	**Month**	**>100kW**	**<=100kW**	**independent of capacity**
	February	400.00	450.00	450.00
2009	August	400.00	450.00	450.00
	February	400.00	450.00	450.00
2010	August	392.04	441.05	441.05
	February	372.83	419.43	419.43
2011	August	351.01	394.88	394.89
	February	333.81	375.53	375.54
2012	August	314.27	353.56	353.55
	February	298.87	336.23	336.23
2013	August	281.28	316.55	316.55
	February	268.94	302.56	302.56
2014	August	260.97	293.59	293.59
For each yer n, from 2015 onwards		**1,3 x SMPn-1**	**1,4 x SMPn-1**	**1,4 x SMPn-1**
SMPn-1: Average System Marginal Price for the previous year n-1				
		Model		If sales contract with HTSO by:
		sales price(€/MWh)	**450.00**	**February of 2010**

Source: http://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxzYW1hcmFzc29sYXJ8Z3g6MTUxYzBkYzhjMzRlZDJhOA

Investment Outlay Parameters

Table 5.4: Benchmark Model: Investment outlay parts and costs

Benchmark Model	**Initial Investment project costs**	
Cost type	**Cost (€)**	**% of total cost**
Technical Equipment	368,890.00	82%
Additional Equipment	17,000.00	4%
Environment Formation	32,000.00	7%
Infrastructure works	20,000.00	4%
Parcel	3,000.00	1%
Fixed intangible costs	11,000.00	2%
TOTAL COST	**451,890.00**	100%

5.2 Results over efficiency of the investment project

Under the stated assumptions and initial parameters, we get the results over the benchmark model of the investment project:

Table 5.5: Benchmark model: Results of NPV, Simple Payback and Ratio Analysis

NPV Analysis	
NPV	98,298 €
IRR	10%
Simple Payback Method	
Payback Year	9th year
Ratio Analysis	
Profitability Index	22%

The complete table that presents the derivation of Free Cash Flows and results of analysis is Table 3 of the Appendix.

At first glance, we may conclude that the results are positive for the firm that would take on the particular investment project; positive NPV and IRR equals to 10%. The firm should pose a minimum rate for IRR under which the management should reject the decision to develop the investment project. In our case, the interest rate plays the role of the opportunity cost (7%). We should also mention that the IRR is influenced by the Free Cash Flows after the deduction of the interest expensed. Some analysts argue that the FCF should include the interest expenses, representing that way the FCF available to firm. It is evident that if we included the interest expenses in our results, we would have even higher NPV and IRR. However, we will continue the analysis taking into account the FCF after the deduction of interest expenses, as the classical FCF analysis approach suggests.

The simple payback method indicates that the management will be able to pay off the initial investment outlay after almost 9 years. Even if the period seems long, we have to take into account the project-specific characteristics; long-term horizon with certain efficiency and revenues due to FIT policy. Of course, the long period of payback can be explained by the highly leveraged financing scheme and the time needed for the loan settlement, which of course can vary. We investigate the differences in results due to differences in capital financing and borrowing conditions in sections 5.3 and 5.4.

As for the ratio analysis, the results are confirmative; positive and satisfying level of value for the profitability index; the investment in this certain PV plant is profitable according to capital budgeting techniques. The trends of gross margin and operating margin can help us identify trends in the numbers for a company from year to year. As already mentioned in chapter 4, Gross Margin functions as a measure of efficiency; its levels, even if slightly decreasing thought time due to the effect of decreasing electricity capacity because of the system's losses, are remarkably high. As fixed costs have to be paid out of Gross Profit, the trend in Gross Margin is indicative of the trend in Operating Margin and in pre-tax profit. Operating margin, thus as expected, also gives satisfying results and the low-cost operating model of the investment project contributes to this direction. Evidently, the rocketing increase of its level in year 15 is due to the full depreciation of the project's assets. The level and trend of Operating Margin differs if we choose different depreciation method and should be considered a supplementary measure, although in our case shows the operating efficiency of the project.

5.3 Sensitivity Analysis – Alternative Models

Even if the investment project has been proven profitable, we must take into account that we based the benchmark model behind the project on certain assumptions and choices. That means that differentiation in research, choices, offers from suppliers and/or initial parameters of financial analysis could lead to different results. That is the reason why we use the sensitivity analysis methodology, so as to obtain general and replicable results. We ended up with five alternatives to the reference model that help us get intuition over the several decisions that an investor has to make for the implementation of the investment project in short-term horizon.

1st alternative: **initial investment cost; evolution and differentiation**

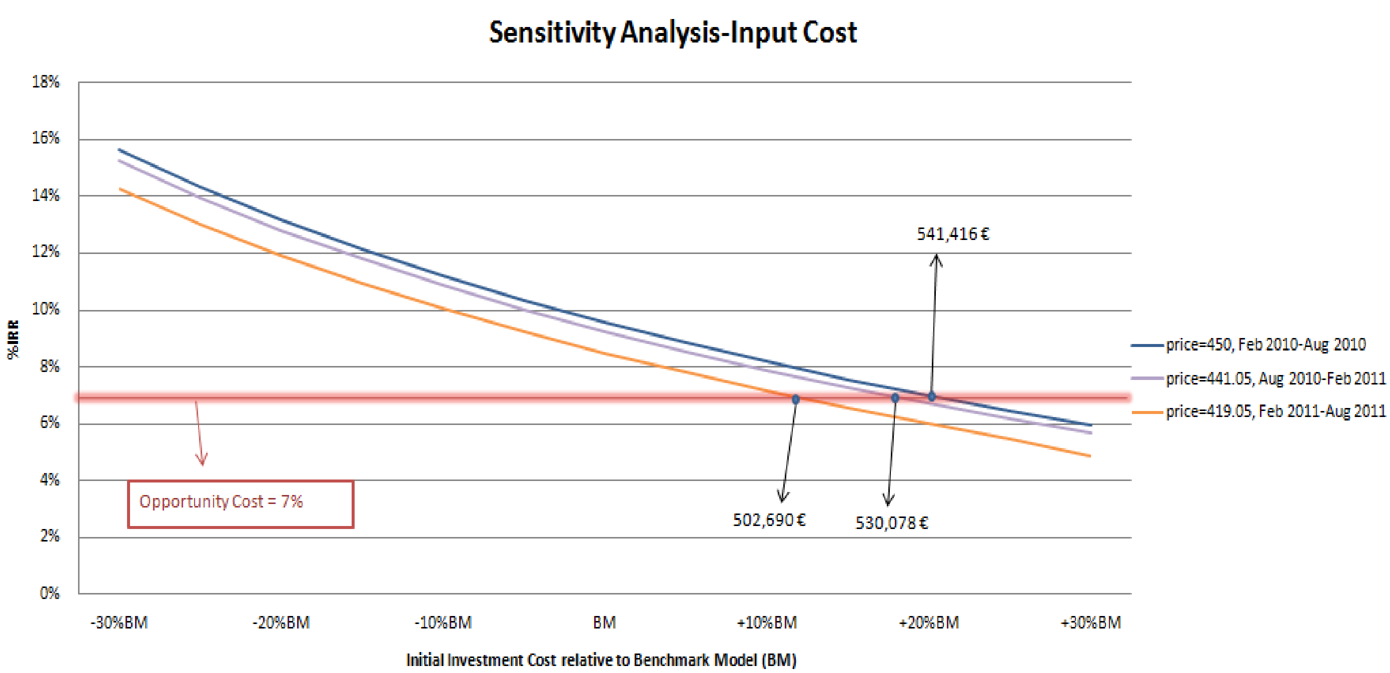
Motivation

The choice of the first alternative model was motivated by the evolution of PVs investment cost the last years; as already proven by section 2.1.5, the mean cost of PV modules decreased significantly the last years due to the elaborated technological learning curve. Leap-frogging and economies of scale contributed to the huge reduction of the overall cost of the project. According to the Solarbuzz (Solar Energy Research and Consultancy Company) solar module price index of its updated report of June 2010, the solar module price fell by almost 14% since 2007. Moreover, the report stresses the predictions that the industry is looking to drive module prices down by even another 80-90% in the next decade if it is to make large inroads in to the grid tied electricity market, without subsidy. Even our research in the retail module prices in Greek market indicated impressing differences in the last 7 months (January to July 2010); as we analyzed in chapter 3, January 2010 was the last month of the investment incentive law that provided grants to the project, apart from the FIT policy. It seems that this change caused market distortions and depressed the initial investment project cost, as the updated offer that we collected from the same supplier company was reduced by around 7% in May 2010. The percentage is indeed impressive if we take into account that the investment cost drops on average of 2.5% each year according to Rexpansion (2005). Even in the same point in time, the research showed remarkable differences in the supplier's offers. The highly dynamic market, the market distortions and the existent variety of offers were the reasons why we chose to investigate the differences in the results taking into account different input costs with the help of sensitivity analysis.

Results

The table with all the results from the first alternative is Table 4 of the Appendix. Figure 5.1 shows the results of the evolution of IRR for the next 3 prices, as determined by the de-escalating FIT policy (the important is when the sales contract with HTSO S.A. is signed). In relation to the initial investment outlay as derived from our research and the benchmark model, we estimated the evolution of IRR for a reasonable range [-30%, +30%] with reference to benchmark model's initial cost.

Figure 5.1: Results of IRR for the Sensitivity Analysis to Initial Input Cost of the project (BM); 1st Alternative



Commenting the figure above, we could mention some basic points:

- As expected, as we increase the investment input cost the IRR decreases, given that all the other defined parameters remain the same. As a matter of fact, the form of each curve shows that the IRR decreases at a higher rate than the rate of cost's increase; IRR decreases with an increasing rate. The project is highly sensitive to the input cost necessary for its implementation; an investment cost lower with 20% than the cost of the benchmark model leads to an IRR higher by almost 38%.

- For IRRs below the opportunity cost rate, the management should reject the investment project. In the figure, this critical point corresponds to an input cost level for each price level. For the benchmark model (price=450, February 2010 to August 2010) this level is almost 20% above the estimated cost; the margin is significant which can only be translated as positive for the potential of the project.
- As for the rest two price levels, the margin is lower. This implies decreasing rate of return through time, since the investment cost decreases at a lower rate compared to the rate of FIT de-escalation, under the same assumptions.

We choose not to expand our results for longer periods of time, because we focus our interest on the change of policy and its meaning for a potential investor in short-term period of time. According to Dancev et al (2010), in long-term horizon, the de-escalating FIT poses the project unattractive as the time passes; as a matter of fact they prove that after January 2015 the investment in this market will no longer be attractive unless a required reduction in the investment cost ensures that IRR maintain at reasonable levels. Their results show that unless real energy prices increase dramatically, the investment cost shrinks substantially or the current investment scheme is radically modified, the investment in new PVs projects will most probably be discontinued in Greece after 2014.

Trying to approach realistically the potential of the project in the future, we focus on the de-escalated prices; 7% reduction of prices for the next year (2011) and a 10% reduction for each of the three years that follow. Unless the technology learning curve covers the price reduction rates satisfyingly, the future potential of the project seems unpromising.

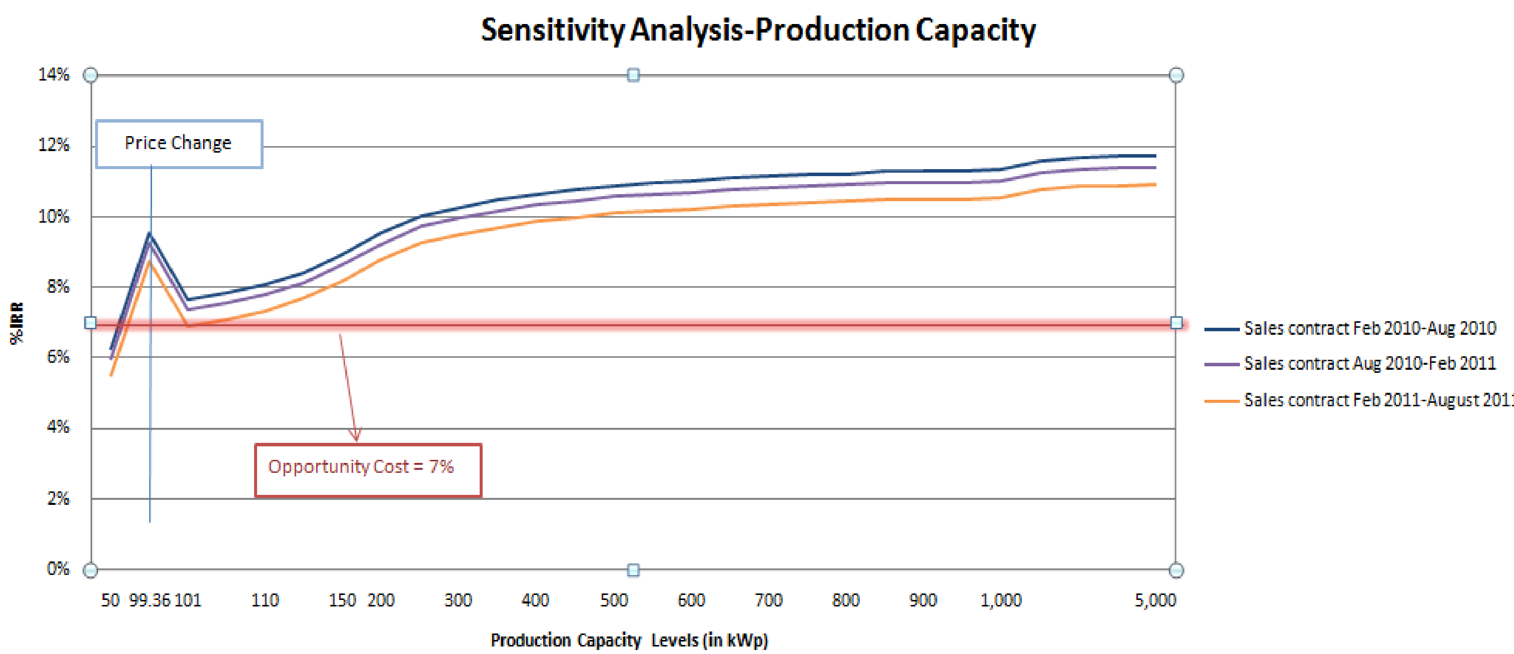
2^nd^ alternative: production capacity levels

Motivation

One of the most important choices the potential investor has to make concerns project's level of production capacity. For different capacity levels, many parameters change; initial cost (number of panels, trackers, inverters of technical equipment, parcel needed, depreciated value and additional consulting costs for levels higher than 1 MWp are the most important categories of cost that need to be adjusted), as well as prices for capacity levels higher than 100 KWp. It is interesting to examine the relation of cost and efficiency that results in the evolution of IRR for given capacity levels. The de-escalating FIT drives the trends of efficiency, as illustrated by IRR in figure 5.2.

Results

Figure 5.2: Results of IRR for Sensitivity Analysis to Production Capacity Levels; 2nd Alternative



Commenting the results of figure 5.2, we could mention that:

- What first strikes us is the discontinuation in trend of all three curves because of the price change, for capacity levels higher than 100 KWp. We now prove the reasonable choice we made for our benchmark model; capacity level close but below 100 (99.36 KWp), so as to take advantage of the higher price, as determined by the FIT policy. As we notice, for capacity levels close and above 100KWp the efficiency of the project falls rapidly and approaches the opportunity investment cost. Comparatively, we could state that the same levels of IRR as those just before the price change are reached for capacity levels of around 200KWp.
- The three curves follow the same trend even though they move at different levels. We should mention at this point an important assumption for the implementation of the particular sensitivity analysis; we assumed that the initial investment cost remains the same for each one of the capacity levels and for the cases that the sales contract is signed until August 2010 or until

February 2011, given the relatively significant reduction in 2010 (as explained in the 1st alternative model). For the next de-escalated price level (contract from February 2012 till August 2012) we assumed an additional reduction of 2% of the initial cost. What seems to happen in the trends is that until the capacity of 100KWp the 3 lines are close to each other, but this seems to stop for capacity levels above 100KWp. More particularly, for contracts signed from February-August 2011, the project's efficiency seems to diverge away more from the next curve of Aug2010-Feb 2011, than the latter from Feb 2010-Aug 2010 (blue and purple line closer to each other than purple with yellow). Those differences are caused by the differences of the de-escalated prices.

- The general outline of the trends of all three curves is that IRR starts from levels below the opportunity cost and increases until the price change (for capacity levels higher than 100 KWp). Then, IRR rapidly falls because of the negative relation of input cost and cash inflows (lower price). Afterwards and as the capacity levels increase in the figure, IRR first increases with increasing rate, but this does not continue until the end; after 300KWp, IRR increases with decreasing rate and seems to stabilize for capacity levels above 1MWp (IRR equals to 11-12%). The small "kink" for capacity equal to 1,000 KWp is due to some additional intangible fixed assets for projects bigger than 1MWp; for this category of projects some additional consulting costs that concern environmental reports have to be paid by the investor.

Therefore, depending on the capital that the investor can provide for the particular project, the sensitivity analysis of the 2nd alternative model gives intuition over the optimal decision of the project's capacity levels in short-term horizon.

The results of the sensitivity analysis to production capacity levels are presented in Table 5 of the Appendix.

3rd alternative: Different technology

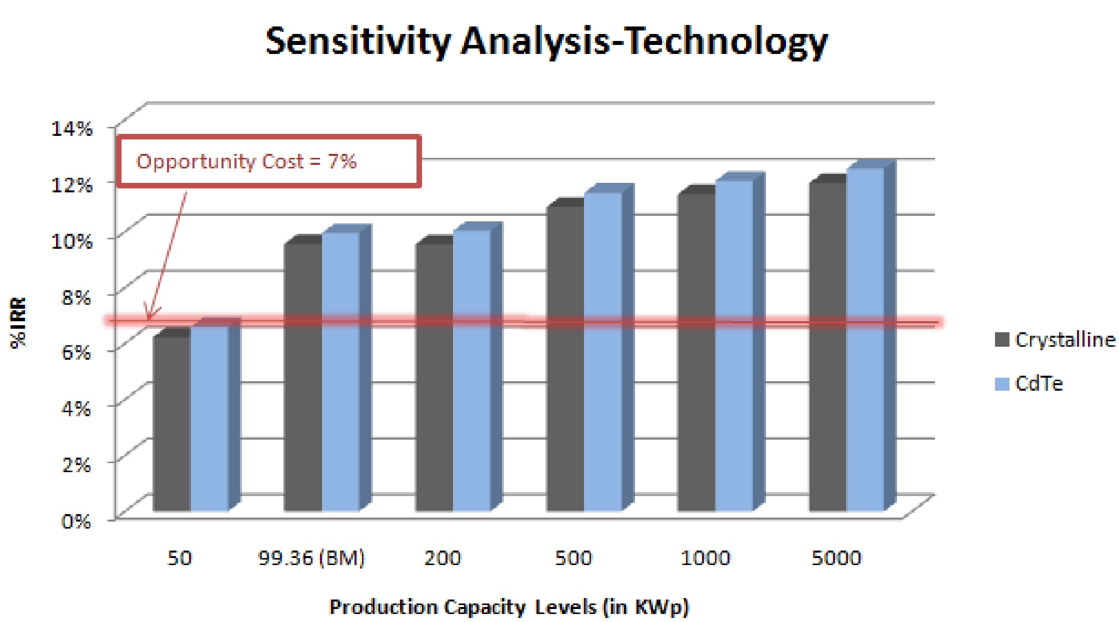
Motivation

In chapter 2, while presenting the parts of the investment project, we distinguished in a separate section (section 2.1.5) the most important technologies of PVs panels available at the market; different characteristics, efficiencies, costs. That is the reason why we chose a different technological input to compare the efficiency of the project. Our interest orientated at CdTe technology because it performs better in high temperatures. Given the high average of temperatures due to the project's location, we wanted to approach another perspective, even if the existent competitor-projects widely use crystalline technology. The problem with this technology (thin solar technology) is that first of all they have lower efficiencies as far as the electricity produced is concerned. However, more significant hurdle is that its technical long-term viability has not yet been proven empirically or by relevant academic research; we are not in position to know if their nominal efficiencies can last for the 20 years of the project's expected life.

Results

Indeed while collecting the electricity production data with the help of the PVGIS software, we noticed a significant difference in system's losses due to temperature resistance of the used technology. For the implementation of the sensitivity analysis of this model, we had to adjust the input cost (about 18% lower than the corresponding of benchmark model according to the supplier's offer) and depreciated value, the electricity produced capacity per year and the system's losses. The assumptions under which we implemented the sensitivity analysis of the 3rd alternative model and the results are presented in Table 6 of the Appendix. The results are also illustrated by figure 5.3.

Figure 5.3: Results of IRR for Sensitivity Analysis to Technology; 3rd Alternative



Scanning the figure, the IRR of CdTe technology seems to be slightly higher than the IRR of Crystalline technology for the project's different capacity levels. This could open new horizons of options for the potential investor, under the condition, of course, that the theoretical efficiencies of CdTe technology would be empirically proven to last. However, we have to stress the fact that, at the present, the option of using CdTe is considered as risky; from our own research, the supplier company that gave the offer for both multi-crystalline and thin solar panels, warned us that no warrantee is given for the CdTe efficiency duration. It is, therefore, reasonable that crystalline technology prevails in the PV modules market until today. Nevertheless, if proven to be reliable, thin solar technology is very promising and can open new horizons to solar modules market.

4th Alternative: use/no use of trackers

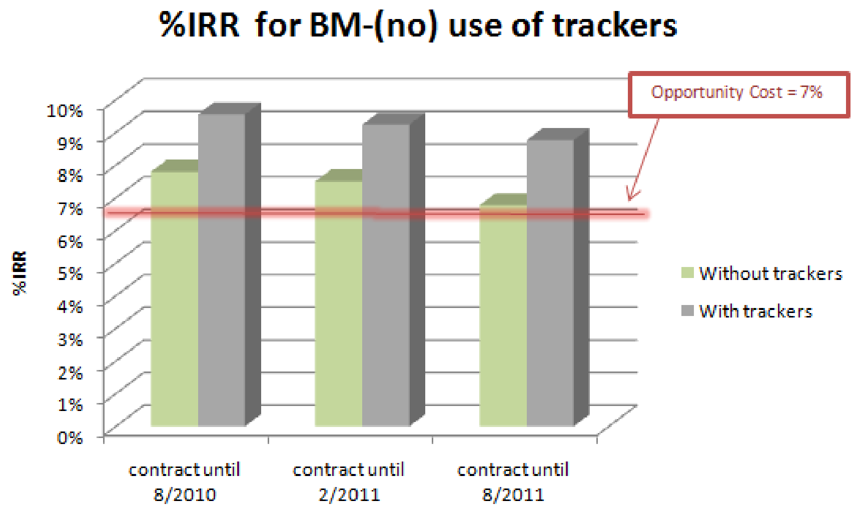
Motivation

The potential investor of a PV power project has another decision to make; the use or no use of trackers. As described in section 2.1.5, trackers allow movement of the panels so as to follow the sun during the day ensuring higher efficiency of KWh per KWp; 28% higher efficiency is theoretically proven (PVGIS software), but there are possibilities of even 35% higher efficiency, depending on other technical characteristics and the location of the project. As a matter of fact, the supplier company, from which we collected the offers, guarantees an increase of 30% when compared to fixed-basis systems. On the other hand, we estimated that the trackers cover about 30% of the total initial investment cost. It is therefore interesting to investigate the relation of cost and efficiency that results in different levels of IRR.

Results

While implementing the sensitivity analysis for the use or no use of trackers, we had to adjust the efficiencies (according to PVGIS software), the investment cost (fixed instead of moving bases) and the depreciated values. Our results are presented in the next two figures.

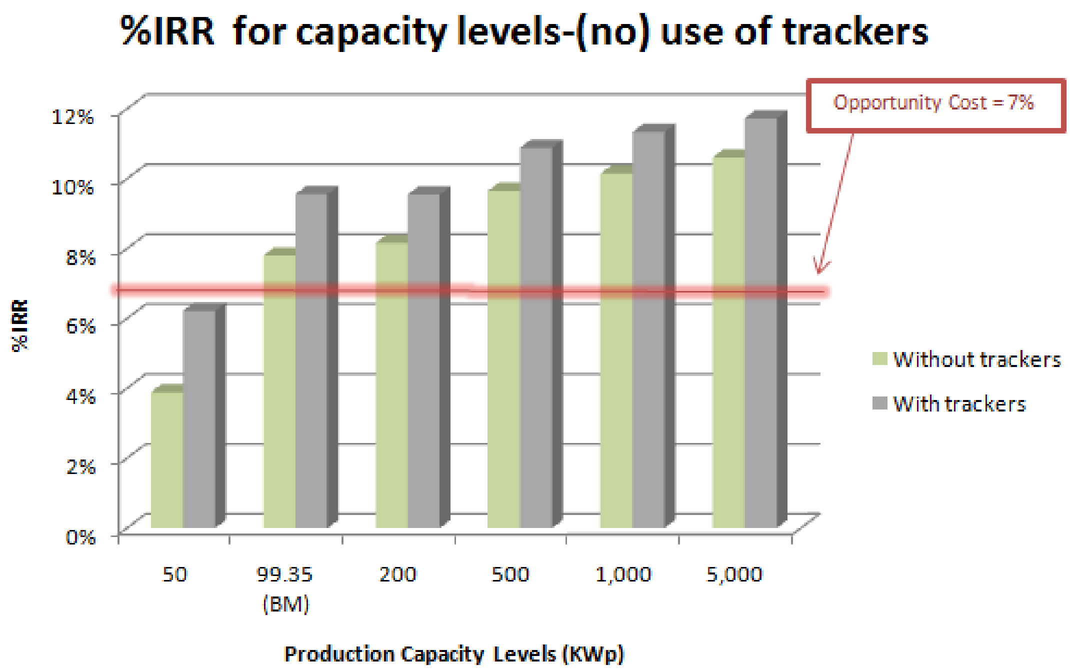
Figure 5.4: Sensitivity Analysis for the Benchmark Model-4th Alternative; (no) use of trackers



It is evident from the results that the use of trackers increases the IRR of the total project, taking into account all the relevant parameters; the use of trackers increase the project's IRR by almost 2 points for each one of the 3 case of de-escalated prices. It is impressive that for the case of signing the sales contract from February to August 2011, the use of trackers leads to a healthy and efficient project with an IRR of 9%, but the corresponding project without the use of trackers is in danger to be rejected, as the IRR is above but very close to the opportunity cost of the investment.

We reach the same conclusion when we investigate the project's efficiency for each production capacity level. As we can see in figure 5.5, the IRR of the project with trackers is always higher by almost 2 points when compared to the project with fixed basis system. The striking point of the results is that for lower capacity levels the difference of the two compared projects' IRRs are bigger than the corresponding difference for higher levels of capacity. Further analysis of the results showed that the latter can be explained by the relation of the adjusted investment cost and the theoretically proven electricity production for projects with and without the use of trackers; the relative difference is higher for lower levels of capacity.

Figure 5.5: Sensitivity Analysis for each capacity level-4th Alternative; (no) use of trackers



We can conclude, therefore, that the use of trackers in a PV power project affects positively its IRR. Finally, if we rely on the empirical results that point at even higher percentages of efficiency than the theoretically suggested (for projects with the use of trackers), we could conclude that the use of trackers should be definitely included in the project.

The results for the sensitivity analysis of the fourth alternative model are presented in table 7 of the Appendix.

5th Alternative: Financial Parameters

Motivation

Finally, we choose to investigate 3 important financial input parameters of the benchmark model; the capital financing scheme of the project, the discount rate and the cost of borrowing. Evidently, the last model does not concern project specific characteristics as the previous 4, but rather general financial parameters.

Results

The results of the alternative model 5 are presented in Table 8 of the Appendix.

Capital Financing Scheme of the Project

We investigated all the potential schemes for the capital financing of the investment project, so as to cover all the potential investors' budgets. As expected, as the leverage increases the IRR decreases almost linearly; the maximum IRR of the benchmark model, under the same assumptions, is 12% and is succeeded with a 10%-90% borrowing-own equity scheme. On the other hand, the minimum IRR is 9% and is succeeded with a 90%-10% borrowing-own equity scheme. The differences are due to the settlement of the long-term loan.

Discount Rate

The choice of the discount rate is important for the NPV analysis and depends on the point of view of the analyst. We chose the interest rates to be the discount rate for our NPV analysis of the benchmark model because of the highly leveraged scheme of the project's financing. However, the discount rate may differ for different analyses. We concluded that for the different levels of discount rate, the NPV of the project is sensitive; as a matter of fact as we increase the discount rate the NPV decreases with an increasing rate. The same happens with the profitability index. On the other hand, the IRR remains unaffected as an absolute value; when compared to the interest rates so as to determine the project's efficiency, IRR ends up at the same results as NPV and ratio analysis.

Cost of borrowing

Finally, we investigate how sensitive are our results relative to the choice of interest rates. As we have already seen, the market indicates 7% interest rates at the moment, for long term loans of investment financing. However, the interest rates fluctuate from times to times. As expected, as we increase the interest rates the IRR decreases. The sensitivity analysis shows the first negative results (project rejected) for interest rates of 9%, given than the rest of assumptions stand.

5.4 Scenario analysis

We close the analysis by presenting the divergence of results under two main scenarios; the worst and best case scenario. The driving forces that lead to the project's efficiency results are chosen according to the sensitivity analysis results of the previous section. We end up, therefore, to the table below:

Table 5.6: Potential choices that lead to the worst and best case scenarios of a PVs project

	Worst Case Scenario	**Best Case Scenario**
Technology	Multi-crystalline panels	Multi-crystalline panels
	No Trackers	With Trackers
Electricity produced/year	149,000 KWh/year	170,000 KWh/year
Investment Cost		
+5% of the estimated	429,296 Euros	
-5% of the Benchmark Model		413,000 Euros
Capacity	99.36 KWp	99.36 KWp
System's Losses	0.9% per year	0.7% per year
Discount Rate	10%	7%
Leverage = Borrowing/Equity	80%/20%	25%/75%
Interest Rates (Loan)	8%	6%
Sales Contract with HTSO S.A.	Signed until August 2011 (price=419.43)	Signed until February 2011 (price=441.05)

According to the parameters as determined by Table 5.1, we end up with the results presented below.

Table 5.7: Results of the Scenario Analysis (Worst Case-Best Case)

	Worst Case Scenario	**Best Case Scenario**
NPV	(83,212)	172,895
IRR	7.13% *(<8%)*	11.88% *(>6%)*
Profitability Index	-20%	40%
Payback Year	10	7

As we have chosen the two extremes scenarios, the divergence of the results is remarkable. Even if we have proven by the analysis of the benchmark model that the project results in low-risk long-term profits, an investor that makes "bad" choices or does not follow the market's opportunities will have troubles planning a profitable project; the worst case scenario is rejected. However, under the assumption that the investor acts rationally we expect positive and encouraging results.

CONCLUDING REMAKS

The recently introduced FIT policy in Greece changed the country's PVs market scene. The transition signals many changes in the market and in the electricity generation sector. The updated changes of the policy (Law 3851/2010), which were just voted in June 2010, give priority in sales contracts with HTSO S.A. to farmers. As a matter of fact, there is already a huge interest by a remarkable number of farmers in all over Greece; the current financial distress of the country makes people look for long-term investments of low risk. The results of the present paper show that an investment in PVs in Greece, under the current legal framework and market conditions, covers those criteria. Under the appropriate guidance, this interest may lead to distributed electricity generation in the country, cover the deficit in the electricity balance or even promote the electricity exports in the long-run. Another aspect is that the policy is a big step for the promotion of RES in the country and, along with the enactment of the Regulatory Authority of Energy and the HTSO S.A. (the "Operator"), the deregulation of the country's electricity market does not seem impossible.

The relevant PVs market research showed that the technological learning curve is the most important characteristic which can raise the potential of a related investment. New technologies seem promising but, at the present, no adequate academic research or empirical proof supports their long-term use. A further research of the project's technological scope is, therefore, highly suggested; higher efficiencies and lower investment outlays would lead to certain and remarkably increased returns on the investment.

Even if throughout the first 3 chapters of the paper we proved that an investment project in PVs in Greece, under the new legal framework and the current technological/market conditions, leads to low-risk and certain returns, our analytical part indicates that the choices of an investor are very important. With the help of the sensitivity analysis methodology, we choose to investigate the influence of the different options available to investors in the short-run. The results show significant divergence of the project's efficiency for the different options.

However, in case that investors act rationally and do an extended market research so that they have sufficient market information, the investment project in PVs in Greece, under the current legal and market conditions, is economically viable. We prove, therefore, that our null hypothesis is true; with the help of Cash Flow Analysis, NPV Analysis, Ratio Analysis and Simple Payback Method we reached positive results for the benchmark model, which was built under clearly stated assumptions. In addition to the latter, the sensitivity analysis indicated the critical values for which the project is economically efficient, and the results are encouraging. The further research sub questions give intuition over the limits and potentials of the project and actually lead to the answer of the null hypothesis.

Finally, we could comment that the next years of Greek electricity market will give an image of how efficient is this kind of "green incentives" and how they can affect the country's market on the whole.

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APPENDIX

Table 1: Production Process

	Constr Period	***Start of production***																			
Start year of investment	2010	2010																			
Years		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
% production development		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Production capacity KWh (no losses)		170,000	170,000	170,000	170,000	170,000	170,000	170,000	170,000	170,000	170,000	170,000	170,000	170,000	170,000	170,000	170,000	170,000	170,000	170,000	170,000
Production capacity KWh (losses incorp)		170,000	168,640	167,291	165,953	164,625	163,308	162,001	160,705	159,420	158,144	156,879	155,624	154,379	153,144	151,919	150,704	149,498	148,302	147,116	145,939

Table 2: Cost of goods sold

			annual costs of goods sold (€)																			
	Cost Analysis	*Construction Period*	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1	Insurance costs		1,356	1,396	1,438	1,481	1,526	1,572	1,619	1,667	1,717	1,769	1,822	1,877	1,933	1,991	2,051	2,112	2,175	2,241	2,308	2,377
2	Security&Maintenance tech costs		1,200	1,260	1,323	1,389	1,459	1,532	1,608	1,689	1,773	1,862	1,955	2,052	2,155	2,263	2,376	2,495	2,619	2,750	2,888	3,032
3	Cleaning&other maintenance costs		1,500	1,545	1,591	1,639	1,688	1,739	1,791	1,845	1,900	1,957	2,016	2,076	2,139	2,203	2,269	2,337	2,407	2,479	2,554	2,630
	Total Costs of goods sold		4,056	4,201	4,353	4,510	4,673	4,842	5,018	5,201	5,390	5,588	5,792	6,005	6,227	6,456	6,695	6,944	7,202	7,470	7,750	8,040

*Notes on Table 2:

1. Insurance costs: concern the amount that the investor has to pay for the insurance of the project in case of any damage or disaster. The market research data showed that the insurance costs in Greece cover around 0.3% of the project’s cost and are assumed to increase by 3% each year
2. Security and Maintenance technology costs: concern the amount that the investor has to pay for the annual maintenance of the project. The supplier’s offer estimated 1,200 euros per year, inflated by 3% each year
3. Extra cleaning and other maintenance costs: concern the amount that the investor has to pay for the annual cleaning of the project and the location, as well as for maintaining the good condition of the project. They are estimated to be 1,500 euros/year, inflated by 3% each year

Table 3: Free Cash Flows Statement and results of the Benchmark Model

	2010										Years of Valuation period										
	PROJECT TOTAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Annual Electricity Production (KWh)	3,153,592	170,000	168,640	167,291	165,953	164,625	163,308	162,001	160,705	159,420	158,144	156,879	155,624	154,379	153,144	151,919	150,704	149,498	148,302	147,116	145,939
State fixed tariff for RES (€/KWh)		0.45	0.45	0.45	0.46	0.46	0.46	0.46	0.47	0.47	0.47	0.47	0.48	0.48	0.48	0.48	0.48	0.49	0.49	0.49	0.49
Revenue	1,486,609	76,500	76,267	76,036	75,804	75,574	75,344	75,115	74,887	74,659	74,432	74,206	73,980	73,755	73,531	73,308	73,085	72,863	72,641	72,420	72,200
(-) COGS	116,412	4,056	4,201	4,353	4,510	4,673	4,842	5,018	5,201	5,390	5,588	5,792	6,005	6,227	6,456	6,695	6,944	7,202	7,470	7,750	8,040
Gross Margin	1,370,197	72,444	72,066	71,683	71,295	70,901	70,502	70,097	69,686	69,269	68,845	68,414	67,975	67,529	67,075	66,612	66,141	65,661	65,171	64,671	64,160
(-) Depr&Amort	448,890	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	0	0	0	0	0
(-) Gen&Ad Exp	19,326	995	991	988	985	982	979	976	974	971	968	965	962	959	956	953	950	947	944	941	939
EBIT	901,981	41,524	41,149	40,769	40,383	39,993	39,597	39,195	38,787	38,372	37,951	37,523	37,087	36,644	36,193	35,733	65,191	64,714	64,226	63,729	63,222
(-) Interests paid	138,015	23,305	21,568	19,707	17,714	15,578	13,291	10,841	8,216	5,404	2,392	0	0	0	0	0	0	0	0	0	0
EBT	763,967	18,219	19,581	21,062	22,670	24,415	26,306	28,354	30,571	32,968	35,559	37,523	37,087	36,644	36,193	35,733	65,191	64,714	64,226	63,729	63,222
Taxable Income	763,967	18,219	19,581	21,062	22,670	24,415	26,306	28,354	30,571	32,968	35,559	37,523	37,087	36,644	36,193	35,733	65,191	64,714	64,226	63,729	63,222
Cumul EBT for tax purposes (2 years)		18,219	37,800	40,643	43,731	47,084	50,720	54,660	58,925	63,539	68,527	73,082	74,610	73,731	72,837	71,926	100,924	129,905	128,940	127,956	126,951
(-) Income Tax	152,793	3,644	3,916	4,212	4,534	4,883	5,261	5,671	6,114	6,594	7,112	7,505	7,417	7,329	7,239	7,147	13,038	12,943	12,845	12,746	12,644
Net Income (NOPAT)	611,173	14,575	15,665	16,849	18,136	19,532	21,045	22,683	24,457	26,375	28,447	30,018	29,670	29,315	28,954	28,587	52,153	51,771	51,381	50,983	50,577
(+) Depr&Amort	448,890	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	29,926	0	0	0	0	0
Free Cash Flow (FCF)	1,060,063	**44,501**	**45,591**	**46,775**	**48,062**	**49,458**	**50,971**	**52,609**	**54,383**	**56,301**	**58,373**	**59,944**	**59,596**	**59,241**	**58,880**	**58,513**	**52,153**	**51,771**	**51,381**	**50,983**	**50,577**

1. **NPV Analysis**	Cost	451,890	
	NPV	98,298	euros
	IRR	10%	
	profitability	22%	

		Years of Valuation period																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2. **Payback period**	Cum Cash Balance	44,501	90,092	136,867	184,929	234,387	285,357	337,967	392,349	448,650	507,023	566,968	626,563	685,805	744,685	803,198	855,351	907,121	958,502	1,009,486	1,060,063
	Payback Year	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE

3. **Ratio Analysis**

Profitability																					
		1				5					10					15					20
Profitability Index	22%																				
Gross Margin		95%	94%	94%	94%	94%	94%	93%	93%	93%	92%	92%	92%	92%	91%	91%	90%	90%	90%	89%	89%
Operating Margin		54%	54%	54%	53%	53%	53%	52%	52%	51%	51%	51%	50%	50%	49%	49%	89%	89%	88%	88%	88%

Table 4: Results from Alternative model 1-Sensitivity Analysis to Input Cost

Alternative 1	*Input cost*													
							B.M.							**Critical Values**
% change	0.7	0.75	0.8	0.85	0.9	0.95		1.05	1.1	1.15	1.2	1.25	1.3	
Input cost	**316,323**	**338,918**	**361,512**	**384,107**	**406,701**	**429,296**	**451,890**	**474,485**	**497,079**	**519,674**	**542,268**	**564,863**	**587,457**	541,416
NPV	247,148	222,340	197,531	172,723	147,915	123,106	98,298	73,490	48,681	23,873	-936	-25,744	-50,552	0
IRR	16%	14%	13%	12%	11%	10%	10%	9%	8%	8%	7%	6%	6%	7%
PI	78%	66%	55%	45%	36%	29%	22%	15%	10%	5%	0%	-5%	-9%	0%
Payback Year	6	6	7	7	8	8	9	9	10	10	10	11	11	10
from August 2010	sales price= 441.05													
Input cost														530,078
NPV	234,699	209,891	185,083	160,274	135,466	110,657	85,849	61,041	36,232	11,424	-13,384	-38,193	-63,001	0
IRR	15%	14%	13%	12%	11%	10%	9%	9%	8%	7%	7%	6%	6%	7%
PI	74%	62%	51%	42%	33%	26%	19%	13%	7%	2%	-2%	-7%	-11%	0%
Payback Year	6	6	7	7	8	8	9	9	10	10	11	11	12	10
from February 2010	sales price= 419.43													
Input cost														502,690
NPV	204,628	179,819	155,011	130,202	105,394	80,586	55,777	30,969	6,161	-18,648	-43,456	-68,802	-101,240	0
IRR	14%	13%	12%	11%	10%	9%	8%	8%	7%	7%	6%	5%	5%	7%
PI	65%	53%	43%	34%	26%	19%	12%	7%	1%	-4%	-8%	-12%	-17%	0%
Payback Year	6	7	7	8	8	9	9	10	10	11	11	12	12	10

reject investment decision

accept investment decision

Table 5: Results from Alternative model 2-Sensitivity Analysis to Production Capacity Levels

Until 08/2010		*price=450*	*price=400*																
production capacity (in kWp)	50	99.36 **BM**	101	110	150	200		300		400		500		600		700		800	900
Corresp cost	274,120	451,890	463,350	491,901	640,589	827,189	1,006,538	1,193,658	1,377,008	1,560,127	1,743,477	1,926,077	2,109,946	2,296,546	2,476,416	2,663,015	2,842,365	3,029,485	3,395,954
NPV	-17,081	98,298	25,327	44,345	105,126	179,881	262,923	337,107	415,757	494,333	572,983	652,130	730,209	804,964	887,435	962,190	1,045,232	1,119,416	1,276,642
IRR	6%	10%	8%	8%	9%	10%	10%	10%	10%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%
PI	-6%	22%	5%	9%	16%	22%	26%	28%	30%	32%	33%	34%	35%	35%	36%	36%	37%	37%	38%
Payback Year	11	9	10	9	9	9	8	8	8	8	8	8	8	8	8	8	8	8	8

from 08/2010		*price=441.05*	*price=392.04*																
production capacity (in kWp)	50	99.36	101	110	150	200		300		400		500		600		700		800	900
Corresp cost	274,120	451,890	463,350	491,901	640,589	827,189	1,006,538	1,193,658	1,377,008	1,560,127	1,743,477	1,926,077	2,109,946	2,296,546	2,476,416	2,663,015	2,842,365	3,029,485	3,395,954
NPV	-23,350	85,849	14,073	32,088	88,408	157,594	235,061	303,677	376,752	449,759	522,835	596,413	668,917	738,104	815,000	884,186	961,654	1,030,269	1,176,351
IRR	6%	9%	7%	8%	9%	9%	10%	10%	10%	10%	10%	11%	11%	11%	11%	11%	11%	11%	11%
PI	-9%	19%	3%	7%	14%	19%	23%	25%	27%	29%	30%	31%	32%	32%	33%	33%	34%	34%	35%
Payback Year	11	9	10	10	9	9	8	8	8	8	8	8	8	8	8	8	8	8	8

from 02/2011		*price=419.43*	*price=372.83*																
production capacity (in kWp)	50	99.36	101	110	150	200		300		400		500		600		700		800	900
Corresp cost (-2%)	268,637	442,852	454,083	482,063	627,777	810,645	986,408	1,169,785	1,349,467	1,528,925	1,708,607	1,887,555	2,067,747	2,250,615	2,426,887	2,609,755	2,785,518	2,968,895	3,328,035
NPV	-32,472	65,701	-2,912	13,310	62,128	121,974	189,925	249,211	312,859	376,449	440,097	504,246	567,334	627,180	694,572	754,417	822,369	881,655	1,008,892
IRR	5%	9%	7%	7%	8%	9%	9%	9%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
PI	-12%	15%	-1%	3%	10%	15%	19%	21%	23%	25%	26%	27%	27%	28%	29%	29%	30%	30%	30%
Payback Year	11	9	10	10	9	9	9	9	8	9	8	8	8	8	8	8	8	8	8

	+3,000€ intangibles				
production capacity (in kWp)	1,000				5,000
Corresponding cost	3,764,903	7,439,806	11,111,460	14,782,363	18,454,016
NPV	1,430,781	2,991,830	4,556,449	6,121,890	7,686,508
IRR	11%	12%	12%	12%	12%
PI	38%	40%	41%	41%	42%
Payback Year	8	7	7	7	7

from August 2010	+3,000€ intangibles				
production capacity (in kWp)	1,000				5,000
Corresponding cost	3,764,903	7,439,806	11,111,460	14,782,363	18,454,016
NPV	1,319,347	2,768,962	4,222,147	5,676,154	7,129,338
IRR	11%	11%	11%	11%	11%
PI	35%	37%	38%	38%	39%
Payback Year	8	8	8	8	8

from February 2011	+3,000€ intangibles

production capacity (in kWp)	1,000				5,000
Corresponding cost (-2%)	3,689,605	7,291,010	10,889,231	14,486,716	18,084,936
NPV	1,133,462	2,394,851	3,659,738	4,925,432	6,190,319
IRR	11%	11%	11%	11%	11%
PI	31%	33%	34%	34%	34%
Payback Year	8	8	8	8	8

***Notes on Table 5:**

For each production capacity level, we implemented certain adjustments:

Change in the cost of technical equipment (number of panels, trackers, inverters) and corresponding depreciated value
Change in the cost of the area needed (parcel)
Addition of a cost of 3,000 € of intangible fixed assets (consulting costs for environmental research) for capacity levels above 1 MWp (according to law 3851/2010)
Change in the sales price when capacity is higher than 100 KWp (according to de-escalating FIT of Law 3851/2001)
For the sales contract signed from February 2011 till August 2011 we adjusted the cost, assuming a reduction by 2% due to predicted technology learning curve (Rexpansion, 2005)

Table 6: Results from Alternative Model 3-Sensitivity Analysis to Technology

Multi-crystalline						
		price=450	*price=400*			
production capacity(in kWp)	50	99.36 **BM**	200	500	1,000	5,000
Electricity produced (KWh/year)	85,600	170,000	342,200	855,500	1,711,000	8,555,000
Corresponding cost	274,120	451,890	827,189	1,926,077	3,764,903	18,454,016
NPV	-17,081	98,298	179,881	652,130	1,430,781	7,686,508
IRR	6%	10%	10%	11%	11%	12%
PI	-6%	22%	22%	34%	38%	42%
Payback Year	11	9	9	8	8	7

CdTe						
		price=450	*price=400*			
production capacity(in kWp)	50	99.36 **BM**	200	500	1,000	5,000
Electricity produced (KWh/year)	75,200	149,000	301,000	752,000	1,500,000	7,520,000
Corresponding cost	241,225	397,663	727,926	1,694,947	3,310,475	16,236,894
NPV	-8,052	102,716	193,891	666,756	1,438,180	7,729,739
IRR	7%	10%	10%	11%	12%	12%
PI	-3%	26%	27%	39%	43%	48%
Payback Year	11	8	8	8	7	7

***Notes on Table 6:**

1) The cost of the project with the use of thin solars (CdTe) is estimated by reducing by 18% the corresponding cost of the project with the use of crystalline technology, as suggested by the offer of the same supplier (KLT Energy)

2) The efficiencies (KWh per year) according to which the revenues are determined, are estimated by the official PVGIS software

3) The system's losses are reduced to 5% in total, which results in 0.26% annual reduction of electricity produced

3) All the other parameters remain the same as the benchmark model (meaning also the assumption that the sales contract is signed until August 2010)

Table 7: Results from Alternative Model 4- Sensitivity Analysis to (no) use of trackers

Contract until August 2010

WITHOUT TRACKERS		BM *price=450*	*price=400*			
production capacity(in kWp)	50	99.36	200	500	1,000	5,000
Electricity produced (KWh/year)	67,100	133,000	268,000	671,000	1,340,000	6,710,000
Corresponding cost	243,120	393,570	707,189	1,632,077	3,176,903	15,518,016
NPV	-59,262	26,103	68,800	371,112	862,564	4,872,303
IRR	4%	8%	8%	10%	10%	11%
PI	-24%	7%	10%	23%	27%	31%
Payback Year	13	10	9	9	8	8

WITH TRACKERS		BM *price=450*	*price=400*			
production capacity(in kWp)	50	99.36	200	500	1,000	5,000
Electricity produced (KWh/year)	85,600	170,000	342,200	855,500	1,711,000	8,555,000
Corresponding cost	274,120	451,890	827,189	1,926,077	3,764,903	18,454,016
NPV	-17,081	98,298	179,881	652,130	1,430,781	7,686,508
IRR	6%	10%	10%	11%	11%	12%
PI	-6%	22%	22%	34%	38%	42%
Payback Year	11	9	9	8	8	7

Contract until February 2011

WITHOUT TRACKERS		*price=441.05*	*price=392.04*			
production capacity(in kWp)	50	99.36	200	500	1,000	5,000
Electricity produced (KWh/year)	67,100	133,000	268,000	671,000	1,340,000	6,710,000
Corresponding cost	243,120	393,570	707,189	1,632,077	3,176,903	15,518,016
NPV	-67,906	16,364	51,346	327,411	775,292	4,435,294
IRR	3%	8%	8%	9%	10%	10%
PI	-28%	4%	7%	20%	24%	29%
Payback Year	14	10	10	9	8	8

WITH TRACKERS		*price=441.05*	*price=392.04*			
production capacity(in kWp)	50	99.36	200	500	1,000	5,000
Electricity produced (KWh/year)	85,600	170,000	342,200	855,500	1,711,000	8,555,000
Corresponding cost	274,120	451,890	827,189	1,926,077	3,764,903	18,454,016
NPV	-23,350	85,849	157,594	596,413	1,319,347	7,129,338
IRR	6%	9%	9%	11%	11%	11%
PI	-9%	19%	19%	31%	35%	39%
Payback Year	11	9	9	8	8	8

Contract until August 2011

WITHOUT TRACKERS		*price=419.43*	*price=372.83*			
production capacity(in kWp)	50	99.36	200	500	1,000	5,000
Electricity produced (KWh/year)	67,100	133,000	268,000	671,000	1,340,000	6,710,000
Corresponding cost (-2%)	238,257	385,699	693,045	1,599,435	3,113,365	15,207,656
NPV	-81,014	1,480	24,752	257,787	634,442	3,721,424
IRR	3%	7%	7%	9%	9%	10%
PI	-34%	0%	4%	16%	20%	24%
Payback Year	15	10	10	9	9	9

WITH TRACKERS		*price=419.43*	*price=372.83*			
production capacity(in kWp)	50	99.36	200	500	1,000	5,000
Electricity produced (KWh/year)	85,600	170,000	342,200	855,500	1,711,000	8,555,000
Corresponding cost (-2%)	268,637	442,852	810,645	1,887,555	3,689,605	18,084,936
NPV	-32,472	65,701	121,974	504,246	1,133,462	6,190,319
IRR	5%	9%	9%	10%	11%	11%
PI	-12%	15%	15%	27%	31%	34%
Payback Year	11	9	9	8	8	8

*the annual electricity produced without the use of trackers is estimated by the official PVGIS software

Table 8: Results from Alternative Model 5 – Sensitivity Analysis of Benchmark Model to Financial Parameters (Capital Structure, Interest rates, Discount Rate,

BM																	
Equity	90%	85%	80%	75%	70%	65%	60%	55%	50%	45%	40%	35%	30%	25%	20%	15%	10%
Borrowing	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%
NPV	171,701	166,055	160,408	154,762	149,115	143,469	137,823	132,176	126,530	120,883	115,237	109,591	103,944	98,298	92,651	87,005	81,359
IRR	12%	12%	11%	11%	11%	11%	11%	11%	10%	10%	10%	10%	10%	10%	9%	9%	9%
PI	38%	37%	35%	34%	33%	32%	30%	29%	28%	27%	26%	24%	23%	22%	21%	19%	18%

BM							
Discount rate	7%	8%	9%	10%	11%	12%	13%
NPV	98,298	56,309	19,022	-14,196	-43,882	-70,492	-94,417
IRR	10%	10%	10%	10%	10%	10%	10%
PI	22%	12%	4%	-3%	-10%	-16%	-21%

BM									
Interest rate	5.0%		6.0%		7.0%		8.0%		9.0%
NPV	227,110	192,202	159,182	127,921	98,298	70,204	43,537	18,204	-5,881
IRR	10.3%	10.1%	9.9%	9.7%	9.6%	9.4%	9.2%	9.0%	8.8%
PI	50%	43%	35%	28%	22%	16%	10%	4%	-1%