ISCTE Business School
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SOLAR ENERGY IN PORTUGAL

- Development perspectives based on a comparison with Germany -

Rodrigo Pedro da Piedade Coelho Virgilio

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Supervisor:
Prof. António Robalo, Prof. Catedrático, ISCTE Business School, Departamento de Gestão

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Resumo

A energia solar é uma das energias renováveis que apresenta maior potencial de desenvolvimento futuro. Portugal é um dos países da Europa com melhores condições para a utilização da energia solar, mas não é certamente um dos países que melhor as têm aproveitado. Interessa, pois, saber porque é que Portugal não tem aproveitado a energia solar e potenciado o seu desenvolvimento de acordo com a sua vasta disponibilidade. Por outro lado, a Alemanha tem aproveitado a energia solar como nenhum outro país e é actualmente uma das nações líderes neste sector. Através de um estudo comparativo dos mercados de energia solar fotovoltaica e solar termal de Portugal e da Alemanha, concluiu-se que a diferença de desenvolvimento entre os dois países é em grande parte resultado das diferentes políticas adoptadas. Ou seja, o desenvolvimento da energia solar depende não só da radiação solar de cada país, mas sobretudo das políticas adoptadas para promover o seu desenvolvimento e dinamizar os respectivos mercados. De acordo com as conclusões deste estudo comparativo e tendo em consideração as futuras tendências do sector da energia solar, foram definidas uma série de orientações estratégicas para o futuro desenvolvimento da indústria solar em Portugal.

Palavras-chave:
Energias Renováveis, Energia Solar, Políticas de Desenvolvimento, Portugal-Alemanha

JEL Classification:
Q42 – Fontes de Energia Alternativa
Q43 – Política Governamental

Abstract

Solar energy is one of the renewable energies that has greater potential for future development. Portugal is one of the European countries with better solar conditions, but is certainly not one of the countries that has been taking the best advantage of it. It is therefore appropriate to know why Portugal is not using and developing solar energy in accordance with its wide availability. On the other hand, Germany is using solar energy as no other country and is currently one of the leading nations in this sector. After a comparative study of the photovoltaic and solar thermal markets in Portugal and Germany, the conclusion is that the different stage of development between the two countries is largely the result of the different policies adopted. That is, the development of solar energy depends not only on the solar radiation of each country, but above all on the policies adopted to promote its development and enhance these markets. According to the findings of this comparative study and taking in consideration the trends in the solar energy sector, a set of strategic guidelines for the future development of solar industry in Portugal was defined.

Keywords:
Renewable Energies, Solar Energy, Development Policies, Portugal-Germany

JEL Classification:
Q42 - Alternative energy sources
Q43 - Government Policy

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List of abbreviations

ADENE	Agency for Energy (Portugal)
APREN	Renewable Energies Association (Portugal)
AQSpP	Solar Hot Water for Portugal
BIPV	Building Integrated Photovoltaic
BSW	German Solar Industry Association
CAGR	Compound Annual Growth Rate
CO_2	Carbon Dioxide
CPLP	Community of Portuguese Language Countries
CSP	Concentrating Solar Power
DGEG	Directorate-General for Energy and Geology (Portugal)
EEG	Renewable Energy Sources Act (Germany)
EPIA	European Photovoltaic Industry Association
ESTIF	European Solar Thermal Industry Federation
EU	European Union
E4	Energy Efficiency and Endogenous Energies Programme (Portugal)
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GW	Gigawatt
GWh	Gigawatt-hour
IEA	International Energy Agency
IEA-PVPS	International Energy Agency - Photovoltaic Power Systems Programme
INETI	National Institute of Engineering, Technology and Innovation (Portugal)
IPP	Independent Power Producer
IRS	Individual Income Tax (Portugal)
IT	Information Technology
kcal	Kilocalorie
kW	Kilowatt
kWh	Kilowatt-hour
kWp	Kilowatt-peak
kWth	Kilowatt-thermal
LNEG	National Laboratory for Energy and Geology (Portugal)

MW	Megawatt
MWh	Megawatt-hour
MWp	Megawatt-peak
MWth	Megawatt-thermal
PNAC	National Programme for Climate Change (Portugal)
PNAEE	National Plan of Action for Energy Efficiency (Portugal)
PV	Photovoltaic
QUERCUS	National Association of Nature Conservation (Portugal)
R&D	Research and Development
RCCTE	Rules for the Thermal Features Behaviors of Buildings (Portugal)
RE	Renewable Energies
RES	Renewable Energy Sources
SDWH	Solar Domestic Hot Water
SRM	Micro-Production Registration System (Portugal)
strEG	Electricity Feed Act (Germany)
VAT	Value Added Tax

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Sumário Executivo

Portugal é um país com uma forte dependência externa de combustíveis fósseis, mas é também um país dotado com abundantes recursos naturais que permitem o desenvolvimento e aproveitamento das energias renováveis. Um dos recursos naturais mais importantes de Portugal é a sua elevada exposição solar, principalmente quando comparada com outros países europeus situados mais a norte, tal com a Alemanha. No entanto, o desenvolvimento da energia solar na Alemanha é bastante mais aprofundado do que em Portugal, tornando-a uma das Nações líderes em termos de implementação e produção de sistemas de aproveitamento da energia solar. A explicação das diferenças de desenvolvimento entre Portugal e a Alemanha, através de uma análise comparativa, será a base fundamental para se chegar a conclusões concretas quanto ao real estado do desenvolvimento da energia solar em Portugal.

A dinamização das energias renováveis em Portugal ocorreu sobretudo desde o século 21, e o país está nestes últimos 3 anos a passar por uma fase de forte desenvolvimento da energia solar. Na origem desta dinamização e forte desenvolvimento, estão com certeza as influências das políticas energéticas da União Europeia sobre políticas energéticas nacionais, os planos nacionais de Eficiência Energética, a legislação específica criada para fomentar o aproveitamento das energias renováveis, e a elaboração de programas específicos de apoio ao aproveitamento da energia solar, entre outras razões importantes.

Ainda que os *drivers* do desenvolvimento da energia solar na Alemanha sejam semelhantes aos de Portugal, a situação na Alemanha é substancialmente diferente. O desenvolvimento das energias renováveis na Alemanha tem ocorrido desde os anos 90, pelo que este país tem já muita experiência em políticas de apoio às energias renováveis, e mostra um desenvolvimento muito profundo do sector da energia solar, seja em termos de investigação, produção ou implementação de sistema solares.

No que respeita à energia solar fotovoltaica, ambos os países têm em vigor um sistema de *feed-in*, sendo que ambos apresentam importantes diferenças em termos de valores das tarifas, de prazos, de características dos sistemas e de limitações. O sistema Alemão, pelas suas características e por ser bastante mais experimentado que o sistema Português, parece induzir mais confiança aos investidores. O reflexo disso pode-se confirmar através da diferença de desenvolvimento das indústrias solares fotovoltaicas entre ambos os países. No final de 2008

a Alemanha tinha uma capacidade instalada de cerca de 64.61 kWp por 1,000 habitantes enquanto Portugal tinha apenas 5.52 kWp por 1,000 habitantes.

No que respeita à energia solar termal, actualmente em ambos os países está definida a obrigatoriedade de instalação de colectores solares termais na construção de novas habitações, num determinado conjunto de circunstâncias. Esta obrigatoriedade é muito importante para a dinamização do sector, no entanto, não deverá ser encarada como a única medida de promoção deste tipo de energia. Principalmente na Alemanha, que apresenta um forte e consistente desenvolvimento desde os anos 90, ainda antes de existir essa obrigatoriedade, medidas como a implementação de programas de apoio específicos, incentivos fiscais e subsídios, entre outros, foram fundamentais para o actual estágio de desenvolvimento do sector. Também neste sector a diferença entre os dois países é muito significativa. No final de 2008 a Alemanha tinha uma capacidade instalada aproximada de 134 m^2 por 1,000 habitantes e Portugal tinha apenas 37 m^2 por 1,000 habitantes.

Esta comparação entre as duas realidades serve não só para se ter uma imagem do real desenvolvimento do sector da energia solar em Portugal e da adequabilidade das politicas e das medidas adoptadas para fomentar o seu desenvolvimento, mas também, juntamente com uma análise das actuais tendências do sector solar, para definir uma série de orientações estratégicas para o futuro desenvolvimento da energia solar em Portugal.

Entre outras medidas, que incluem uma aproximação em determinados aspectos da legislação portuguesa à legislação alemã, inclui-se ainda a sugestão da definição de metas ambiciosas por parte dos Executivos, do desenvolvimento de programas de implementação de equipamentos de energia solar em instalações públicas e em instalações privadas de grande dimensão, da aposta de uma forma harmoniosa na produção de energia centralizada e descentralizada, da optimização das relações entre empresas e universidades no campo da investigação e desenvolvimento e do aumento da notoriedade deste tipo de fontes energéticas.

A concorrência de países tecnologicamente mais avançados ou de países com baixos custos produtivos é uma das principais ameaças à afirmação e ao desenvolvimento futuro da indústria solar portuguesa. Contudo, se Portugal conseguir potenciar os pontos fortes e as oportunidades, desenvolvendo políticas consistentes e coerentes, provavelmente conseguirá ser uma referência e exemplo para outras nações ao nível do aproveitamento da energia solar.

Executive summary

Portugal is strongly dependent on foreign countries in what concerns fossil fuels, but is also a country with plenty of natural resources, allowing the development and use of renewable energies. One of the most important natural resources in Portugal is its high solar radiation, especially when compared with the northern European countries, such as Germany. However, the development of solar energy in Germany is much more advanced than in Portugal, making it one of the leading nations in terms of implementation and production of solar energy systems. The explanation of the development differences between Portugal and Germany, based on a comparative analysis, will be the essential basis to find concrete conclusions about the actual condition of solar energy development in Portugal.

In Portugal, the renewable energies boosting took place mainly in the 21st century and, for the last 3 years, the country has experienced a period of strong development in solar energy. Behind this boosting and strong development are, for sure, the influence of European Union energy policies, the national plans for energy efficiency, specific legislation to encourage the renewable energies use and specific programmes supporting solar energy exploration, among other important reasons.

Although the drivers of solar energy development in Germany and Portugal are similar, the German situation is considerably different. The renewable energies growth in Germany has been occurring since the 90s, giving it a wide experience in policies for renewable energies' development and showing a much greater advance in the solar energy sector, in terms of research, production and implementation of solar systems.

Regarding photovoltaic solar energy, both countries have a feed-in tariffs' system in force, but they present major differences in terms of tariffs values, deadlines, systems features and limitations. The German system, for its characteristics and for its longer experience, seems to offer more confidence to investors. The result of this can be confirmed by the development gap between both countries concerning photovoltaic solar industries. By the end of 2008, Germany had an installed capacity of about 64.61 kWp per 1,000 inhabitants, while Portugal only had 5.52 kWp per 1,000 inhabitants.

Concerning solar thermal energy, in both countries, and in a particular set of circumstances, the installation of solar thermal collectors in new buildings is currently mandatory. This requirement is very important to boost the sector, however, it should not be seen as the only measure to promote this type of energy. In Germany in particular, where there is a strong and consistent development since the 90s, even before that requirement, measures like the implementation of specific support programmes, tax incentives and subsidies, among others, were essential to achieve the current development stage of the sector. Also in this sector, there are significant differences between the two countries. By the end of 2008, Germany had an installed capacity of about 134 m^2 per 1,000 inhabitants and Portugal only had 37 m^2 per 1,000 inhabitants.

This comparison between both realities intends not only to present an overview of the real development of solar energy sector in Portugal and the suitability of the adopted policies and measures to foster its development, but also, along with an analysis of the current trends in solar sector, to set strategic guidelines for the future development of solar energy in Portugal.

Among other measures, which include an approach of Portuguese legislation to Germany's in certain issues, it is also included the suggestion of setting ambitious targets by the Executive, the development of programmes for implementation of solar energy equipment in public and large private facilities, the harmonious support to centralised and decentralised energy production, the optimisation of the cooperation between companies and universities in R&D and the increase of awareness of this type of energy sources.

The competition from more technologically advanced countries or from countries with low production costs is one of the main threats to the consolidation and future development of Portuguese solar industry. However, if Portugal is able to enhance its strong points and opportunities, by developing consistent and coherent policies, it will probably become a reference and an example for other nations concerning solar energy use.

Introduction

Scope and objectives

The world energy mix is rapidly changing. Issues such as energy security, recent trends of high volatility in oil prices and global concerns regarding climate change and sustainability have highlighted the importance of renewable energies (RE) in the future energy mix. There are different opinions from different experts in the energy sector. Some state that RE will never be a real alternative to fossil energy sources and to nuclear energy while others argue that RE should be the basis for the future world energy strategies, mainly for its importance to the world sustainability. Recently this discussion gained even more momentum due to the world economic crisis and also because it has become a top priority of the new Administration of the United States of America.

In Portugal, a country heavily dependent on external energy sources, the government is taking decisive steps to foster the use of RE, making use of the resources available in the country. With abundant resources in different renewable areas such as wind, ocean, hydro, biomass and sun, there are bold and innovative plans both from the public and private sectors to develop new RE projects. However, the future development of RE lies almost entirely on hydro and wind energy as an alternative to polluting fossil fuel energy sources.

Additionally to favourable national political conditions for the development of RE, also the ambitious targets assumed by the European Union (EU) help keep the pace to all member states. Within the EU, Germany has become over time an example for other countries. It is one of the world's top producers of RE and its government is clearly focused on becoming less dependent on fossil energy sources and is planning to phase out nuclear power plants.

Given the general overview in the energy sector, and with such different opinions about the importance of RE in future energy strategies, this document aims to assess and analyse the real importance and role of one of the most available and less used RE in Portugal - solar energy.

Portugal is one of the countries in Europe with higher solar radiation per year, but it does not take the best advantage of it. In a country that is still highly dependent on fossil and foreign energy resources, and where the endogenous energy resources are only partially used, it is difficult to understand the current low strategic importance of solar energy, a widely available resource, in the energy portfolio and its poor development as a driver of economic growth in Portugal. It is therefore interesting to analyse how and why a country like Germany, with clearly less solar resources than Portugal, is one of the worlds top solar sector developers, while Portugal is still in a starting and uncertain situation in what concerns solar energy development.

Considering Germany as a best practice due to its current status and influence in the solar sector, and comparing policies and measures adopted by both countries and their impact in this sector's development, it will be clearer what strategies Portugal should follow in the future to become an industry reference.

Another objective of this thesis is to clarify readers and possible consumers about the importance of solar energy. This research is an opportunity to help promote the usage of renewable energies sources (RES), and to give a small contribution to increase the awareness of such important issues, that will for sure determine the sustainability of our planet.

In order to address these issues, this document will be divided in four different chapters. The first chapter is a brief introduction to the RE topic, including its definition and an overview of its major different types. Also in this first part there will be a quick analysis of non-renewable energies, the so-called "traditional" sources of energy, essentially to establish a comparison between the renewable and non-renewable energies, and to better understand the differences and consequences of future energy options. Finally, in this first part the importance of the RE in Portugal will be analysed. The idea is to get a clear picture of the particular situation of this sector in Portugal.

In the second chapter the focus will be on solar energy in particular. It will be analysed its historical importance and the differences of the current major solar technologies available will be defined. Technical aspects will be addressed as well as future and potential innovations. The aim is to clarify some basic issues related with solar energy, and to establish a temporal analysis from the past to the future, underlying the increasing importance of this sector.

In the third chapter, the particular situation of solar energy development, both in Portugal and Germany, will be analysed. This analysis will focus on the policies adopted by these countries, and their impact on the sector development. After this analysis, a direct comparison will be developed in several different areas to clearly identify what Portugal is doing well and not so well, comparing to the best practices in the sector.

In the fourth and final chapter, and taking into consideration all the previous analysis and also recent trends in the industry and economy in general, the discussion will be over the strategies for solar energy in Portugal. The idea is to identify the particular issues and areas where Portugal should put an extra effort to boost the sector.

Data collection methodology

In the preparation of this document, both primary and secondary research was used for data collection. The author spent the winter semester of 2008/09 in Germany, under the double degree programme of both ISCTE Business School, in Lisbon, and Pforzheim University, in Pforzheim. During this period spent in Germany, the author faced the reality of one of the most developed countries in the solar energy area, confirming the high degree of implementation of such technologies. In addition, during the semester, the author took courses where subjects such as climate change, sustainability, environmental policy, EU policies, RE and German industry were deeply addressed, and he had the opportunity to talk with teachers, students and other citizens about solar energy in Germany. In Portugal, unstructured interviews were conducted with several experts in the RES area, including a former responsible for Directorate General for Energy and Geology (DGEG), the President of the Renewable Energy Association (APREN), the responsible for Renewable Energies in the National Laboratory for Energy and Geology (LNEG) and the National Association of Nature Conservation (QUERCUS).

Secondary data was gathered from national and international reports and data bases, of both public and private institutions or organisations, such as, for example, DGEG, Ministry of Economy and Innovation or the Agency for Energy (ADENE) in Portugal, the Federal Ministry for the Environmental, Nature Conservation and Nuclear Safety, The Fraunhofer-Gesellschaft or the German Solar Industry Association (BSW) in Germany, and International Energy Agency (IEA), Directorate-General for Energy and Transport of the European

Commission, European Solar Thermal Industry Federation (ESTIF), or the European Photovoltaic Industry Association (EPIA), as well as several other sources that compile data related to the issue. The legislation of both Portugal and Germany was also a fundamental information source. In addition, several newspapers, magazines and books were used to provide the latest developments and information about RE and specifically about solar energy. The author also attended the Lisbon Innovation and Renewable Conference in 2008, and gathered information from this and other forums and conferences such as the Lisbon Energy Forum, or the IV Renewable Energies Conference.

1. Renewable energies

There are different definitions for the concept of RE. In essence, all the definitions are similar and one can conclude that the term renewable resource has mainly two different meanings. Either it means a perpetual resource that is in no danger of long-term availability, or it can also refer to resources that are harvested in a sustainable way. In contrast, a non-renewable resource is the one that will eventually end because it doesn't renew itself.

Typically RES include six different types of energy, namely, solar, wind, hydro, ocean, geothermal and bioenergy.

Solar energy is the radiant light and heat from the sun that can be harnessed as a clean energy source of heat and electricity. The sun is the world's primary source of energy, however only a minuscule fraction of the available solar energy is used. In general, the energy from the sun can be used in three main ways: passive heat, photovoltaic and solar thermal. Passive heat is the heat that the earth receives from the sun naturally. Usually this is taken into account in the design of buildings as a way of reducing energy consumption. Photovoltaic (PV) is a word that derives from two other words: photo (light) and voltaic (electricity). So PV power generation uses solar cells to convert light directly into electricity. Solar thermal is another way of using solar energy, and it is based on a simple principle that has been used for long - the sun heats up water contained in an appropriate reservoir. Nowadays solar thermal can also be used in a cooling system to create air conditioning with heat absorption systems.

Wind energy is used to create useful power, such as electricity, using wind turbines. It has also been used for centuries to generate power other than electricity, and it is considered as one of the most promising renewable energy technologies, mainly because of its efficiency. "*Modern wind turbines extract energy from the wind by transferring the momentum of passing air to rotor blades. The power generation depends on the density of the air, wind speed and turbine size. ...Energy is concentrated into a rotating shaft and converted into electricity*" (Directorate-General for energy and transport, 2007:15). There are two different types of wind farms. The onshore are the wind farms placed on land and the offshore wind farms are the ones placed on water.

Usually, hydro energy refers to the production of electricity using the movement from a mass of water (gravitational force of falling or running water), such as a river or a stream, driving trough a water turbine and generator. In most cases, the water is dammed to be used according to the power necessities. After being used the water is returned to its natural course. Normally hydro refers to large-scale schemes with large dams and storage reservoirs. However there are also the small hydro sites that are generally defined as those with installed capacity of less than 10 Megawatts (MW) and with smaller infrastructures.

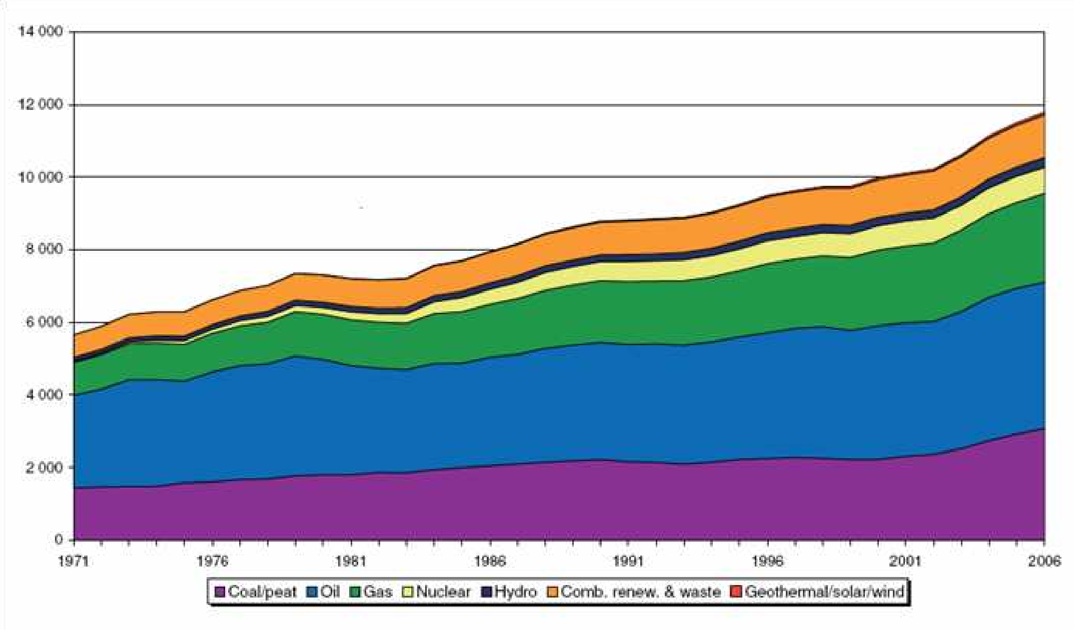
"*Ocean energy comes from energy flows such as waves, tides, ocean currents, as well as differences in salinity and temperature*" (Directorate-General for Energy and Transport, 2007:16). Oceans cover three quarters of the planet area, and that is why ocean energy has a huge potential in the future. Normally ocean energy can be divided in wave power and tidal power. Wave power is the transport of energy by ocean surface waves, and the capture of that energy to do useful work. Tidal power is generated by the natural ebb and flow of tidal waters. "*This can be done either by harnessing the rise and fall of the sea level using barrages, or by drawing energy from tidal currents using turbines in a way comparable to wind power*" (Directorate-General for Energy and Transport, 2007:16).

Geothermal energy is generated from heat stored in the earth, or the collection of absorbed heat derived from underground. "*It is extracted from the earth's natural heat in dry, steam or liquid form and can be used for electricity and heating*"(Directorate-General for Energy and Transport, 2007:18). It has been used for centuries for bathing and heating water, and nowadays it is also used in electricity generation in a power plant that requires water or steam at a very high temperature, and it can also be used for geothermal heat pumps that use stable ground or water temperatures near the earth's surface to control building temperatures above ground.

Bioenergy is a renewable energy derived from biological sources, to be used for heat, electricity, or vehicle fuel. Bioenergy can be extracted from Biomass which is derived from different types of organic matter like energy plants and forestry, agricultural or urban waste. Biomass can be used for biofuels, to replace fossil fuels in the transport sector. Both biodiesel and bioethanol are liquid fuels processed from agricultural crops or plants. Biomass can also be used for biogas which is produced by the process of anaerobic digestion of organic material by anaerobes.

The most important non-renewable energies are the so-called fossil fuels and also the nuclear energy. Fossil fuels include gas, oil and coal, all exhaustible resources, and they still represent the majority of energy consumption all over the world. Nuclear energy depends on uranium to its production, which is also an exhaustible resource, and it represents an important energy source to the group of countries that have nuclear power plants. The next graph, shown in figure 1, developed by the IEA, shows the world energy production by source from 1971 to 2006.

Figure 1 - World energy production by source (Mtoe[1])



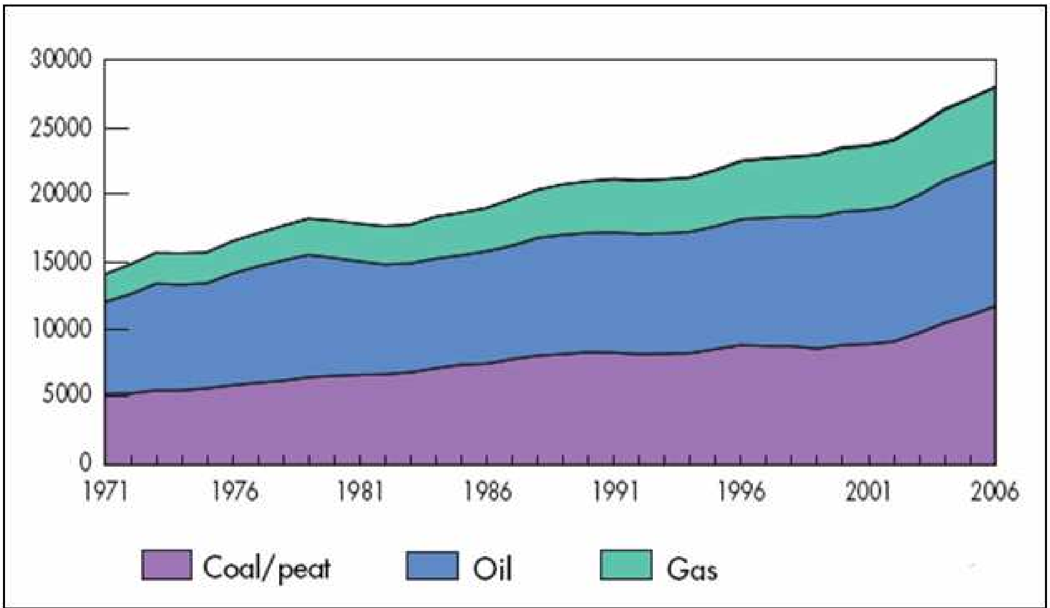
Source: IEA

From the analysis of this graph it is clear that oil, gas and coal have been the major energy sources during these years, and RE account only for a very small part of the world's total production during this period of time. It is also clear that energy production has increased about twice the values of 1971, being the fossil fuels the great contributors to this production increase. Obviously, the production increased because the energetic needs of different countries also increased in a similar proportion. One of the most serious consequences of this energy consumption based on fossil fuels during this period is the increase of Carbon Dioxide (CO_2) emissions, as well as other greenhouse gas (GHG) emissions, and its effects on climate change.

[1] Mtoe - Millions tonnes of oil equivalent

Figure 2 shows the evolution of world CO_2 emissions by fuel type from 1971 to 2006. As expected, with the increasing evolution of world energy production, the emissions of CO_2 also increased in a similar proportion.

Figure 2 - World CO_2 emissions by fuel (Mt^2 of CO_2)



Source: IEA

Even if energy cannot account for all the GHG emissions around the world, the energy sector is the major cause of this problem since the burning of fossil fuels to produce energy is the main source of GHG emissions. According to IEA (2007) at a global level, it is responsible for over 60% of total emissions. Reducing GHG emissions, and consequently mitigating climate change, will require several specific actions and will involve a big change in a wide range of fields. Naturally the energy sector will also have to be included as one of the most affected. In this domain, a radical change is expected in the production, transformation and usage of energy sources.

But why should we use RE? Is it the climate change the only reason to do it? Well, it is one of the most important reasons but not the only one. Energy security and local economic development are also appointed as typical advantages of RE over fossil fuels.

RE emit small amounts of GHG and in some cases none at all. There is an increasing concern for the climate change problem, and therefore there are more and more governments and populations focused on decreasing GHG emission and reducing pollution. Promoting the use

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[2] Mt - Million tonnes

of RE has been one of the most important measures to achieve it, and legislation is evolving towards environmental and climate change tackling. Using RE will help mitigate pollution and harmful emissions, and at the same time will contribute to global objectives, and to comply with current legislation.

Energy issues present a global dimension and have direct political, social and environmental implications for producing and consuming countries alike and for trading relationships between them. The production of fossil fuels is getting even more concentrated in countries and zones that are highly unstable politically, and the energy necessities are rising more and more creating big asymmetries and problems between producing and consuming countries, menacing the energy security in some countries. In addition, price fluctuations and logistical difficulties can also arise. Because RE are based on inland natural resources, they are important to reduce country's dependence on fossil fuels imports and to diversify the energy mix.

Finally, the last major reason to use and develop the RE sector is related with economic development. The RE production "*will boost the development of new technologies in the field and create a need for knowledge-based industry*" (Piebalgs, A., 2007), increasing the industrial competitiveness of the country and improving its innovation strategic framework. Enhancing a country's competitiveness will also develop the conditions to create new jobs and innovative businesses.

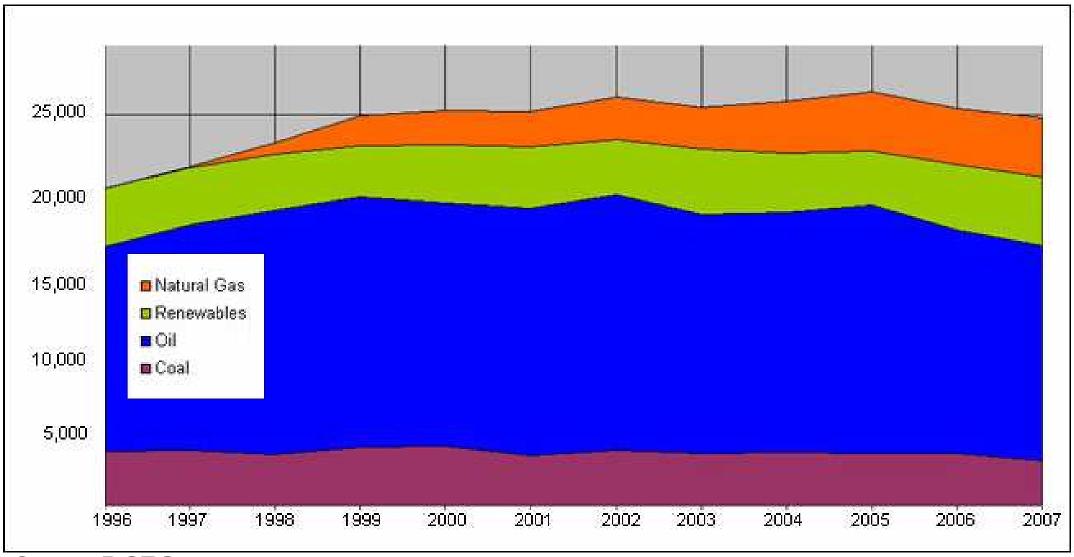
One of the reasons often used to defend the fossil fuels is their relative costs when compared with the RE ones. In fact, concerning RE, the development cost for producers and the final cost for consumers are generally higher than the same costs in fossil fuels. The development of the RE sector has been based on tax incentives, investment grants, quotas systems, green certificates, feed-in regulation, amongst other instruments for its promotion. Nevertheless the price competitiveness of the RE has been improving for the last years mainly because there is also an increasing demand that generates economies of scale and lowers the production costs. And if the external costs of fossil fuels, such as environmental impact, were fully taken into account, RE could be more competitive than the conventional energy sources. That is why, often, a comprehensive economic evaluation of RES is not possible, because at a microeconomic level it does not reflect the fact that conventional energy generation still causes significantly more environmental damage than energy generation from RES. This damage, the so-called external costs, is not yet incorporated into electricity prices as required by the "polluter pays principle".

1.1. Renewable energies in Portugal

Portugal is a country with scarce indigenous energy fossil resources, namely, oil, coal and gas. According to DGEG, Portugal’s shortage in primary energy[3] sources leads to a significant external dependence (82.9% in 2007) which accounts for being dependent on imports of primary sources of fossil origin.

According with the same source, the oil consumption represents the highest portion of the total primary energy in Portugal. In relative terms, it represented 54.0% of the total primary energy consumption in 2007. Gas represented 15.0 % of the total primary energy as a result of the previous 10 years intensification of the usage of this energy source. Coal consumption accounted for 11.3 % of the total primary energy in 2007. Due to its impact on CO_2 emissions it is foreseen a progressive reduction in the usage of coal for electricity production. In 2007, RE represented 17.1% of the total primary energy, against 16.3% in 2006

Figure 3 - Evolution of primary energy consumption in Portugal (Ktoe[4])



Source: DGEG

[3] Primary energy is the energy embodied in natural resources prior to undergoing any human-made conversions or transformations. Secondary energy is generated from the conversion of other energy sources (e.g. electricity)

[4] Ktoe - thousand tonnes of oil equivalent

The energy consumption of the Industry sector was 29.2% of the total energy consumption, and it was 36.4% in Transport, 17.1% in Households, 12.2% in Services and 5.1% in other sectors (which include Agriculture, Fishing, Building and Public Works).

According to the Directorate-General for Energy and Transport (2007:9), the "*European Union (EU) is a world leader in renewable energy and the sector is already economically relevant. Renewable energy in the EU has a turnover of € 30 billion, providing 350.000 jobs"*. However development has been uneven across the EU, and RE still represent only a small share of the EU's total energy mix in primary energy sources, although a significant part of the produced electricity already comes from RE.

Eurostat estimates that, in 2010, over 20% of the EU electricity will be generated from renewable sources. This indicator is the ratio between the electricity produced from RES and the gross national electricity consumption, and it measures the contribution of electricity produced from RES to the national electricity consumption.

In Portugal the indicative target set by the RES - electricity European Directive[5] of 2001 is a 39% share of RES on gross electricity consumption by 2010, one of the highest percentages of EU (see annex 2), mainly due to the importance of hydro energy. This target was already achieved in 2007. However an indicative target of 45% share of RES on gross electricity consumption was set by the government, which means that Portugal still has some effort to put on RE until 2010, even if this new target is not mandatory by the EU Directive.

According to the DGEG information, as of the end of December 2008, the total installed capacity for the production of electric energy from renewable sources was 8,124 MW in Continental Portugal[6], which represents an incorporation of RES in the gross electricity consumption of about 43%.

[5] Directive 2007/71/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market
[6] Portuguese territory with the exception of Madeira and Azores islands

Table 1 - Historic evolution of total installed capacity in RE (MW) in Continental Portugal

	2001	2002	2003	2004	2005	2006	2007	2008
Hydro	4,263	4,288	4,292	4,561	4,752	4,802	4,805	4,810
Wind	114	175	253	537	1,047	1,681	2,108	2,770
Biomass	352	380	360	369	369	381	381	381
Municipal Waste	88	88	88	88	88	88	88	88
Biogas	1.0	1.0	1.0	7.0	8.2	8.2	12.4	12.4
Photovoltaic	1.3	1.5	2.1	2.7	2.9	3.4	14.5	58.5
Waves/tides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2
Total	4,819	4,934	4,996	5,565	6,267	6,964	7,409	8,124

Source: Directorate-General for Energy and Geology, Portugal (2009)

In 2008, hydro energy represented more than 59% and wind energy more than 34% of the total installed capacity in RES. However both these sources are highly dependent on weather conditions and that is why the produced energy can vary enormously, especially for the hydro energy where there are significant variations of the energy produced.

Table 2 - Historic evolution of produced electricity with RE (GWh) in Continental Portugal

	2001	2002	2003	2004	2005	2006	2007	2008
Hydro	14,240	8,096	15,894	10,053	5,000	11,323	10,351	7,102
Wind	239	341	468	787	1,741	2,892	4,007	5,695
Biomass	1,086	1,208	1,112	1,258	1,350	1,380	1,510	1,527
Municipal Waste	511	518	523	475	545	532	498	441
Biogas	2.2	2.5	2.3	14	31	33	55	67
Photovoltaic	1.6	1.8	2.6	2.9	3.8	4.1	23.6	41.4
Waves/tides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	16,080	10,167	18,002	12,590	8,671	16,164	16,445	14,873

Source: Directorate-General for Energy and Geology, Portugal (2009)

In fact, comparing the share of installed capacity of hydro energy in 2008 (~59%) with the real share of hydro energy produced in that year (~48%), it's easy to conclude that the Portuguese renewable energy portfolio has to become more stable, through diversification and increase of the installed capacity.

2. Solar energy

2.1. Quick facts about solar energy history

"*The energy consumed on Earth in a year is supplied by the sun in a single hour*" (Niesing,B., 2009:12) says solar expert Professor Dr. Elicke R. Weber. "*This makes it clear why the direct use of solar energy will have such an important part to play in a global context in the medium and long term*"(Niesing,B., 2009:12).

Even in the past solar energy has played an important role. Ancient Greeks and Romans saw great benefit in solar energy and they used architecture to make use of the sun's capacity to light and heat indoor spaces. Romans and Greeks developed several techniques to take advantage of the sun, using materials such as glass or mica to hold in the heat of the winter sun, decreasing the need to burn wood that was often in short supply.

The PV effect was observed for the first time in 1839, by Edmond Becquerel, who found that certain materials produced small amounts of electric power when exposed to light. However, the earliest known record of the direct conversion of solar radiation into mechanical power belongs to the French Auguste Mouchout, who can be considered as a visionary because he anticipated in the 19th century some of the problems that Europe and the World are facing now. He questioned the widespread belief that the fossil fuels powering the Industrial Revolution would never run out. "*It would be prudent and wise not to fall asleep regarding this quasi-security*", he wrote. "*Eventually industry will no longer find in Europe the resources to satisfy its prodigious expansion. Coal will undoubtedly be used up. What will industry do then?*".

But other events were important for the history of solar energy:

- In the beginning of the 20th century, Albert Einstein was awarded with the 1921 Nobel Prize in physics for his discovery of the law of the photoelectric effect;

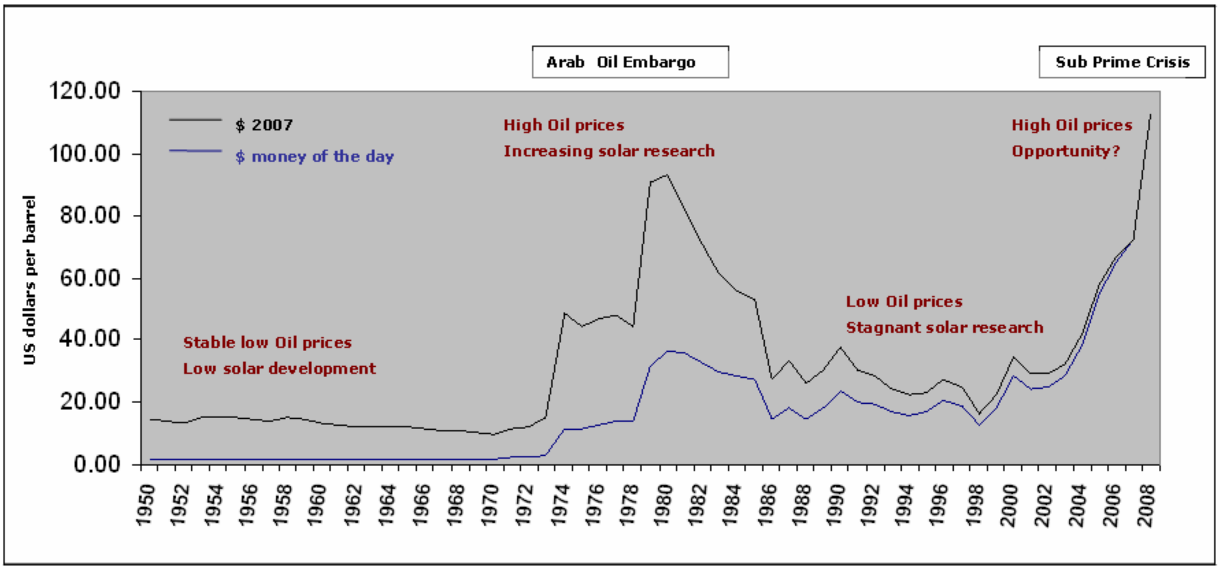
- The first silicon solar cell capable of generating a measurable electric current was developed by scientists Gerald Pearson, Daryl Chapin and Calvin Fuller at Bell Laboratories, in the 1950's. This could be considered as the beginning of Photovoltaics as we know it;

- During the 1950s and 60s the space industry was the only feasible user of solar energy, as satellites and crafts used solar panelling for electricity;

- In 1973, with the Arab Oil Embargo, oil prices increased abruptly and the Western World leaders became desperate to find means of reducing oil dependence. During the 1970s, there was hope that, through massive investment in subsidies and research, solar PV costs could drop and eventually become competitive with fossil fuels;

- By the 1990s, the reality was that costs of solar energy had dropped as predicted, but costs of fossil fuels had also dropped.

Figure 4 - Evolution of Crude Oil prices



Source: Developed by the Author based on the BP statistical review

Somehow, in the past, it seemed evident the direct relation between oil prices and the investment in alternative energy sources. However, nowadays, the increasing concern with climate change and sustainability could additionally and definitely help putting alternative energy sources, such as solar energy, in the spotlight.

2.2. The present

The energy from the sun can be used in several different ways:

Table 3 - Different ways of using the energy from the sun

SUN

Passive Heat: - The heat received naturally from the sun	
Solar Thermal: - Convert solar radiation into heat	► Solar Domestic Hot Water Systems ► Combined Hot Water and space heating or space cooling systems
Photovoltaic: - Convert sunlight into electricity	► Grid-connected systems ► Off-grid systems ► Hybrid systems
Concentrating Solar Power: - Production of electricity through concentrated technology in a thermodynamic cycle	► Parabolic trough solar ► Solar power tower systems ► Solar dish/engine systems

Source: Developed by the Author

2.2.1. Passive Heat

This is the heat naturally received from the sun. Basically there are two factors that contribute to comfort conditions of buildings: its location/disposition, and the quality of materials used in building construction. Passive heat is very important because, besides its insulation and location, when a building is designed to better capture the solar energy available, it becomes easier to reach the perfect comfort conditions with less energy needs. In the summer the concerns are the opposite. The sun radiation should be avoided and natural ventilation should be used to cool down the room temperature.

Passive heat has been used for centuries and nowadays it is reflected through the legislation of different countries, with specific mandatory requirements and conditions in building construction.

2.2.2. Solar Thermal

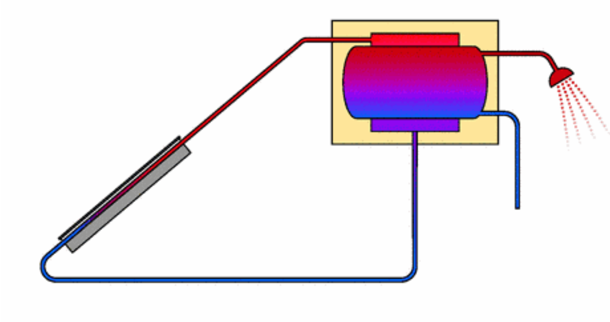
"*The basic principle common to all solar thermal systems is simple: solar radiation is collected and the resulting heat is conveyed to a heat transfer medium - usually a fluid but also air in the case of air collectors*" (ESTIF, 2009). The heated medium is used either directly (e.g. swimming pools), or indirectly, by means of a heat exchanger which transfers the heat to its final destination (e.g. space heating). "*Solar thermal can be successfully applied to a broad range of heat requirements including domestic water heating, space heating, and drying. New exciting areas of application are being developed, in particular solar assisted cooling*" (ESTIF, 2009).

Solar domestic hot water systems (SDHW) are typically used in markets where there is little or no space heating demand. These systems are specifically designed to meet the majority of the hot water requirements in summer and part of them in the winter, depending on the weather conditions and the efficiency of the equipments installed. They can include a supplementary heater (e.g. an integrated electric or gas heater), and they can also operate as pre-heaters.

There are two main different designs of SDHW systems: Thermosiphon and Forced Circulation systems. They differ in the way water circulates between the collector and the tank.

"*Thermosiphon systems use gravity to circulate the heat transfer medium between collector and tank. The medium is heated in the collector, rises to the top of the tank and cools down, then flows back to the bottom of the collector. Domestic hot water is taken either directly from the tank, or indirectly through a heat exchanger in the tank. The main benefit of a thermosiphon system is that it works without a pump and controller*" (ESTIF, 2009). The main disadvantage is the required layout. With this system the tank must be located above or beside the collector. So, either the tank is fastened to the collector and both are situated on the roof, implying considerable architectural impacts and specific technical requirements, or the tank is detached from the collector and is normally installed indoors, for instance just under the roof, implying considerable available space in the attic. The next figure shows a simplified scheme of a thermosiphon system.

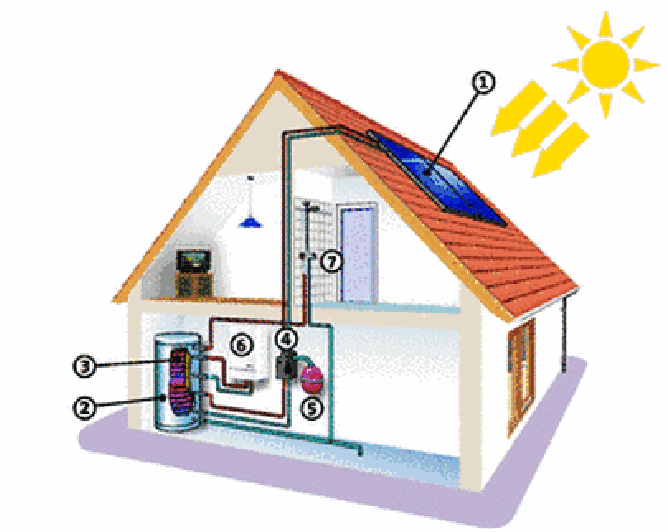
Figure 5 - Thermosiphon system



Source: Solarpraxis AG (ESTIF, 2009)

According to ESTIF (2009), in the Forced Circulation systems the heat transfer fluid is circulated by a pump, so the tank can be installed anywhere. Therefore, integration with other heating systems is easier. Typically, these systems are found in houses, that usually have all equipment installed in the cellar or in annexes (with the exception of the collectors), so the aesthetic and functional impact is lower. This is often one of the main advantages of this type of systems. However, these systems are more complex than the thermosiphon ones. They include sensors, a controller and a pump.

Figure 6 - Forced circulation system



1 - Collector
2 - Tank
3 - Heat exchanger
4 - Control unit
5 - Expansion Tank
6 - Back-up heater
7 - Consumer

Source: Solarpraxis AG (ESTIF, 2009)

Multi-family houses, hotels, office buildings, etc, often use central water heating. In these situations collective SDHW systems can be installed. These collective systems have a collector surface bigger than normal systems. Most of the collective SDHW systems are designed as forced-circulation systems.

Also according to ESTIF (2009), another type of system is what can be defined as a combined system. These systems combine the capacity of providing domestic hot water with the capacity of providing space heating or space cooling. These systems are typically used in markets with colder climate. They imply bigger collector area size and they are more complex than SDHW systems, so the design must be adapted to the specific requirements of each property.

These systems are still rarely found in southern countries, where the climate is warmer, but they have a lot of potential because they have the capacity to supply space heating in winter, air-conditioning in summer and domestic hot water throughout the year.

Sustainability, maturity, resource and technology availability, reliability and low maintenance costs are the most important reasons appointed to choose a solar thermal system. Solar energy replaces fossil fuels, increasing energy security and decreasing dependence from foreign countries, and helps reduce energy bill and GHG emissions. Solar thermal has been used for long all over the world, so it is already a mature technology. The sun is a resource for everyone and there are multiple choices of equipments. The lifetime of these systems is over 20 years requiring low maintenance. Finally and also very important is the price of these systems. They have been decreasing more and more over time, and the payback times are already below the system's lifetime.

2.2.3. Photovoltaic

"*Photovoltaic systems use cells to convert solar radiation into electricity. The cell consists of one or two layers of a semiconducting material. When light shines on the cell it creates an electric field across the layers, causing electricity to flow. The greater the intensity of the light, the greater the flow of electricity is*" (EPIA, 2009). A PV system does not need bright sunlight in order to operate. "*It can also generate electricity on cloudy days. Due to the reflection of sunlight, slightly cloudy days can even result in higher energy yields than days with a completely cloudless sky*" (EPIA, 2009).

Silicon is the most common semiconductor material used in PV cells. This element is most commonly found in sand. Also according to EPIA (2009), "*The most important parts of a PV* *system are the cells which form the basic building blocks of the unit, collecting the sun's light, the modules which bring together large numbers of cells into a unit, and, in some situations, the inverters used to convert the electricity generated into a form suitable for everyday use*".

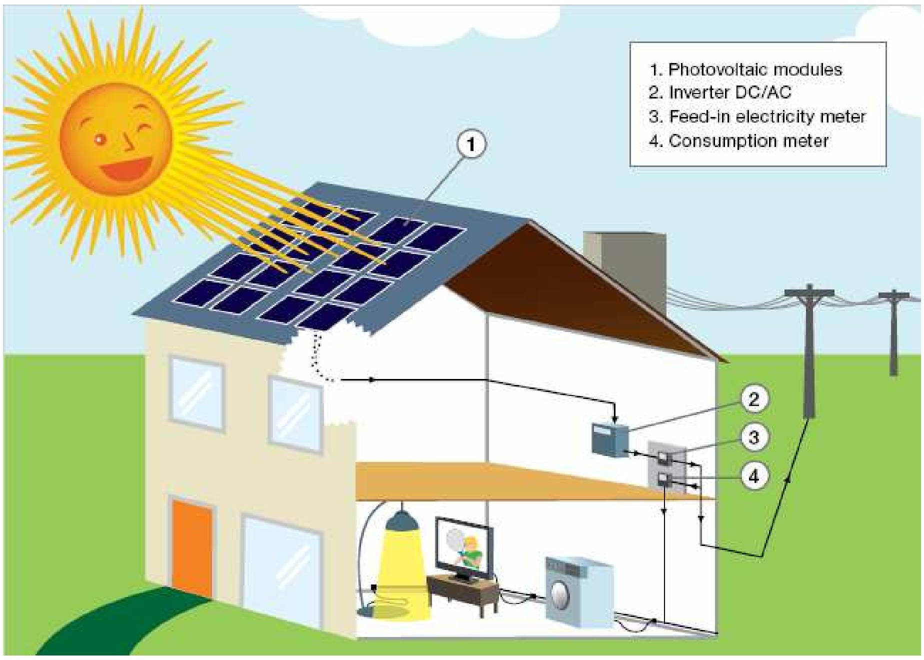
EPIA (2009) also refers that "*the performance of a solar cell is measured in terms of its efficiency at turning sunlight into electricity. A typical commercial solar cell has an efficiency of 15%*". This means that about 15% of the sunlight striking the cell generates electricity. "*Improving solar cells efficiencies while holding down the cost per cell is an important goal for the PV industry*".

Niesing, B. (2009:12), refers that "*One of the problems faced by the photovoltaic industry is that high-purity silicon, the basis of about 90 percent of the world's solar cells production, is getting scarce*". However there are already alternatives. "*Thin-film solar cells made of amorphous silicon, copper indium gallium selenide or even cadmium telluride present a possible solution. These solar cells require little or no silicon, but they also have a significantly lower energy yield*" (Niesing, B., 2009:12). According to EPIA (2009), "*Thin-film modules are constructed by depositing extremely thin layers of photosensitive materials onto a low-cost backing such as glass, stainless steel or plastic*". Other possibilities include flexible cells that are "*based on a similar production process to thin-film cells, when the active material is deposited in a thin plastic, the cell can be flexible. This opens the range of application, especially for buildings integration (roofs-tiles) and end-consumer application*". Another possibility is the use of metallurgical or less pure silicon also known as "*dirty silicon*" (Niesing, B., 2009:12).

The PV technology can be used in several types of applications: grid-connected systems, off-grid systems and hybrid systems.

According to EPIA (2008:18), "*Grid-connected is the most popular type of solar PV system for homes and businesses in the developed world. Connection to the local electricity network allows any excess power produced to be sold to the utility. Electricity is then imported from the network outside daylight hours. An inverter is used to convert the DC power produced by the system to AC power for running normal electrical equipment*". Grid-connected systems allows the development of a structure where private generators can produce and fed the electricity into the public grid, selling it to the grid operators, called feed-in system. In a feed-in system, usually there are pre-defined tariffs (price per unit produced and fed into the grid) for the different energy sources. This is a system often adopted for the promotion of renewable energy sources, through the definition of high tariffs for those energy sources, encouraging customers to produce renewable energy.

Figure 7 - Grid-connected domestic system



Source: EPIA

Off-grid systems are used "*where no mains electricity is available. In this case, the system is connected to a battery via a charge controller .This store the electricity generated for future use and act as the main power supply. An inverter can be used to provide AC power, enabling the use of normal electrical appliances. Typical off-grid applications are repeater stations for mobile phones, electrification for remote areas (mountain huts) or rural electrification in developing countries*" (EPIA, 2008:18). The main advantage of the off-grid systems are its competitive costs *versus* the high cost of developing new infrastructures.

A Hybrid system is the combination of the grid-connected systems or the off-grid systems with another source of power, renewable or non-renewable. These systems are used to ensure a consistent supply of electricity.

The use of PV cells is becoming more frequent in consumer goods of all types, from simple devices as calculators, to professional sun roofs for automobiles. A particular way of using

PV cells and panels is with the concentration photovoltaic technology. This technology is a practical application from space research, and has been used for years in satellites and spacecrafts, where there is a need to obtain the maximum power with the minimum surface. This technology uses very expensive materials to achieve higher efficiencies, including various alternative means to optimise the output and concentrate sunlight such as mirrors and lenses. Another particular way of using PV panels is by its integration in the facades of buildings. This is called Building Integrated Photovoltaic (BIPV).

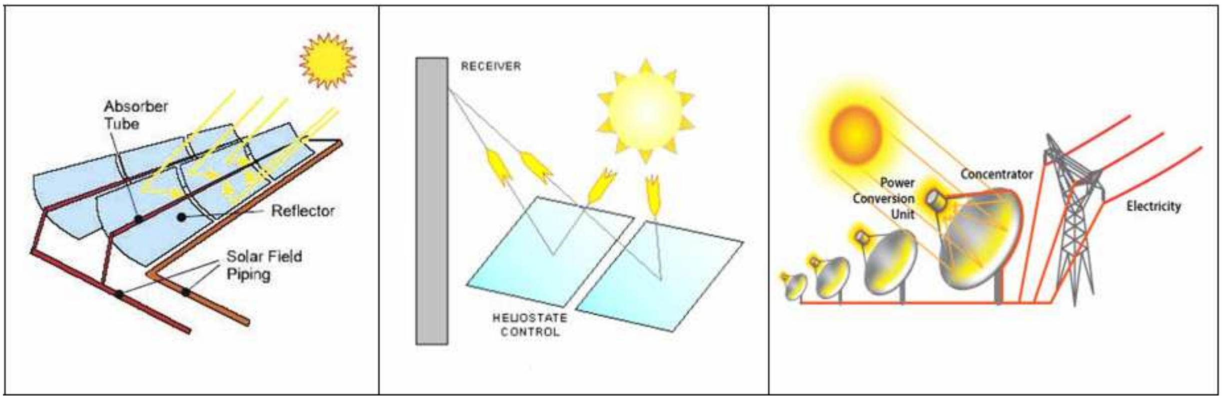
The main advantages of a PV system are similar to a solar thermal system: sustainability, resource and technology availability, reliability and low maintenance costs. A PV system replaces fossil fuel consumption, reducing energy bill, energy dependence from foreign countries and GHG emissions. Moreover, for this type of technology the fuel is free and there are diverse technical solutions, with long lifetime and requiring low maintenance. In addition, no noise is produced, the modules can be recycled and it can bring electricity to remote rural areas. The prices are decreasing with time, and when there is a feed-in system it can be very profitable for consumers.

2.2.4. Concentrating Solar Power

Another way of producing electricity from solar energy is through concentrated technology, "*using solar radiation as a high-temperature energy source to produce electricity in a thermodynamic cycle. The need for concentrating solar arises because solar radiation reaches the Earth's surface with a density (kW/m^2) that is adequate for heating systems but not for an efficient thermodynamic cycle for producing electricity. This means the density has to be increased, and the incoming solar radiation concentrated by using mirrors or lenses*" (European Commission, 2007:7).

The main concepts used in Concentrating Solar Power (CSP) technologies are parabolic troughs, solar towers, or dish/engine systems, which vary according to the concentration devices, energy conversion methods, storage options and other design variables.

Figure 8 - Parabolic trough solar, solar power tower systems and solar dish/engine systems



Source: Clipart

The parabolic curved solar reflectors concentrate the sun's rays to warm up the heat transfer fluid, flowing through the absorber tube, to very high temperatures, producing steam in the heat exchanger. The steam is then used to generate power in the turbines. The solar collectors track the sun continuously to optimise this process.

Solar Power Tower systems use heliostats (mirrors) which follow the apparent motion of the sun, re-directing and focusing the sunlight onto a single receiver placed on top of a tower. The steam produced with the high temperatures of the fluid, is then used to generate power in the turbines.

"*In solar dish/engine systems, parabolic dishes capture the solar radiation and transfer it to a Stirling engine – an engine which uses external heat sources to expand and contract a fluid – placed in the focus of the parabolic dish*" (European Commission, 2007:9)

The main advantage of these power plants is that the fuel is free. Other advantage of these type of thermoelectric centralised[7] systems is that they are very flexible, meaning that it is not difficult to change the technology used to produce electricity. As it is based in a thermodynamic cycle, solar energy can be replaced by other energy sources. The main disadvantage is the high investment needed to implement such power plants, mainly comparing them with traditional fossil fuel power plants. As the materials used are technologically very advanced and unique, they are very expensive. However in the long-run,

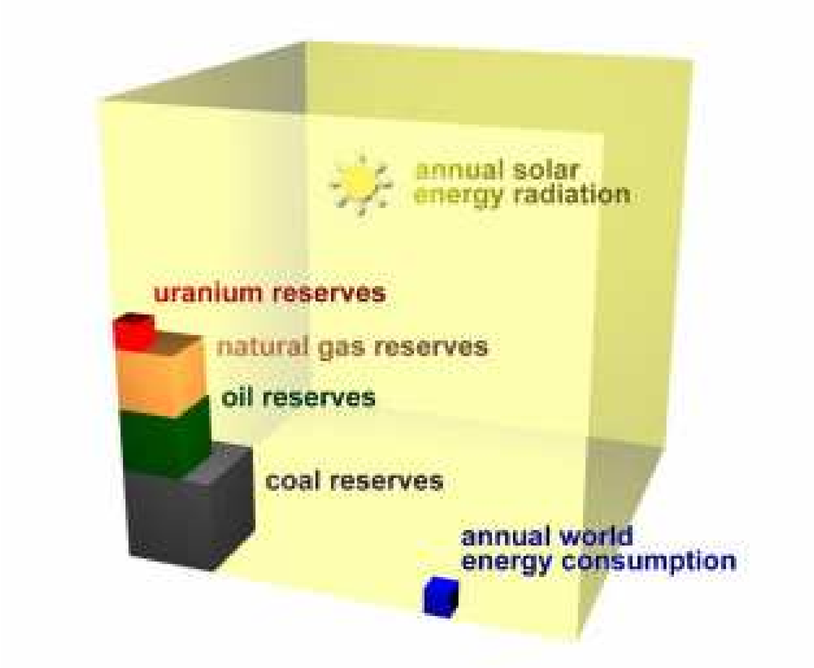
[7] Centralised energy systems - high output production (e.g. power plants). Decentralised energy systems - low output production (e.g. microgeneration)

considering the fact that the fuel is free and the probable decrease of the equipment costs, there are reasons to be optimistic about these technologies. Another important disadvantage is the storage capacity of these power plants. With periods of no solar radiation it is important to develop advanced storage systems to assure a consistent production of electricity.

2.3. The future

The next figure shows the physical solar energy potential in comparison with the fossil fuel energy sources and the annual world energy consumption.

Figure 9 - The physical potential of solar energy



source: Eco Solar Equipment (2009)

Solar energy has an enormous potential and it is more than enough to cover the annual world energy consumption, however only a derisory part of its potential is used. If science and technology continue to evolve as in the past, and taking into consideration the limited capacity of fossil fuel reserves, it is sound to say that in the long term solar energy will play an important role in the energy mix. Companies and research institutes know it, and that is why new products and new technological innovations are becoming more and more common in solar market.

For instance, the company Solar Roadways, the developer of structurally engineered solar panels that are driven upon, developed a product where the concept is to replace all current petroleum based asphalt roads, parking lots and driveways with solar road panels that collect and store solar energy to be used by homes and businesses. Each individual panel consists of three basic layers including a road surface layer, an electronics layer and a base plate layer, which provides all the necessary conditions for the desirable use. Solar Roadways is planning a 21 year lifetime for each panel and announces 15% efficiency (Green Car Congress, 2009).

In Portugal, a country where tiles are an important historical patrimony and often used in architectural projects, an innovative project is being developed. The objective is basically to transform an ordinary ceramic tile in a mini solar panel. This technology is based on PV thin-film, with lower efficiency, but drastically reducing the production costs. This project is still in research, but there is high probability of getting into industrialisation and commercialisation. In the end the important is to get a compromise between the feasibility and efficiency of the product and the aesthetics of the final solution (Rosa, A., 2009).

In solar thermal technologies, the integration SDHW systems directly in the buildings facades and roofs, the implementation of collective SDHW systems with efficient energy management, space cooling systems and thermal energy storage systems, are only some of the fields were technology is expected to rapidly evolve. The simultaneous production of heat, cold and electricity using solar thermal and PV is expected to be a reality in the future (Vasconcelos, S., 2009). Also the technology used in big solar thermal power plants is expected to evolve in order to rapidly decrease the costs of such installations.

3. Solar Energy in Portugal and Germany

3.1. Solar Energy in Portugal

The strongest development of the Portuguese solar energy markets has only occurred in the 21st century. In the 90's these markets were only supported by isolated actions and activities carried out by private investors, associations or consumers.

In 2001 two events, together with EU recommendations, changed the course of RE development. First, the Energy Efficiency and Endogenous Energies (E4) programme promoted by the Government, set on paper numerous targets and assumed the initiative of a group of multiple and diverse actions for RE and energy efficiency. This programme helped to create a new dynamic pace in the sector, changing the way Portugal looks and assesses its endogenous energy resources, establishing objectives such as doubling the electric installed capacity from RES, satisfying a significant part of the domestic and industrial hot water needs through solar thermal and promoting passive solar technologies. The second important event was the Forum of Renewable Energies in Portugal promoted by several public and private organisations and institutions. This forum contributed to identify opportunities and development perspectives to increase the importance of RE and their future role. The participants were divided in different groups according to different RES, and they had to analyse the current situation of that particular source of energy and to propose a set of specific measures and incentives.

Also the influence of EU's recommendations on the national political framework of the state members has been decisive, and Portugal is not an exception on this topic. In 2001 the European Parliament and the Council of the European Union adopted the Directive 2001/77/EC, with the purpose of increasing the contribution of RES to electricity production in the internal electricity market and creating a basis for a future Community framework thereof. The importance of promoting electricity produced from RES was already a high priority for EU as outlined in the White Paper on Renewable Energy Sources, for different reasons such as security and diversification of energy supply, environmental protection and social and economic cohesion.

The following years showed a dynamic country concerning RE, with the development of several specific plans and programmes, constant adaptation of the legal framework, increased discussion, interest of the public opinion and awareness. Currently "*the renewable policy framework in Portugal constitutes a comprehensive policy mix, completed with a monitoring system. However, administrative barriers are often hindering a further development, especially for hydropower and solar technologies*" (European Renewable Energy Council, Portugal review, 2008)

One of the most polemic energy issues in Portugal is the nuclear power. There are no nuclear power plants in Portugal, but several specialists and politicians support that this would be a balanced and secure option for the future, that would promote the Portuguese energy independence. Others support that Portugal does not need nuclear power because there are environmental, security and safety risks with this option.

3.1.1. Photovoltaic in Portugal

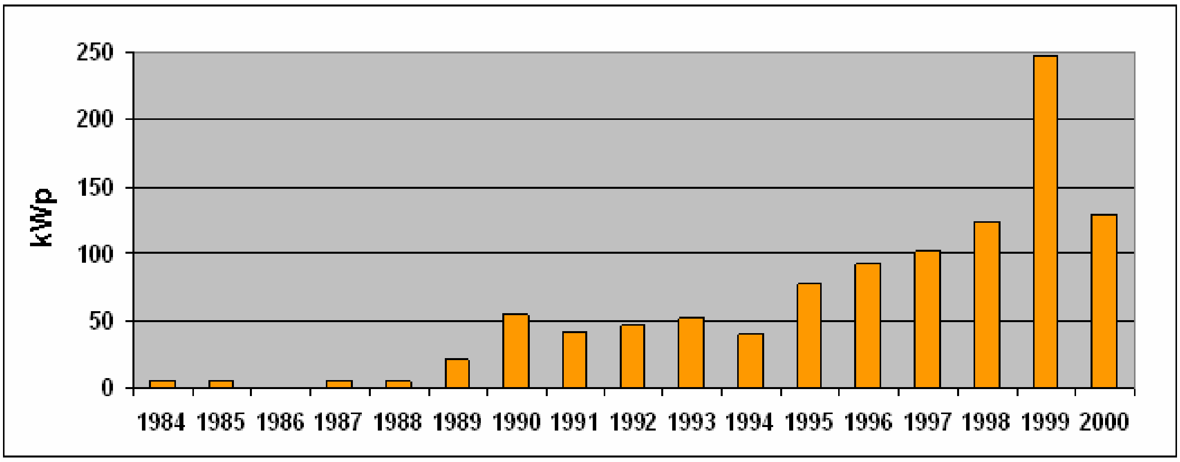
Since the beginning of the 21st century, the PV industry in Portugal has gained more importance mainly due to the EU influence on the energy policies of the different state members. According to EPIA, the solar PV market has been booming over the last years and the forecasts are even more optimistic. The EU is a major player in the global market as it contributes with around 50% of the global cumulative capacity. However the Portuguese development has been slower comparing to other countries like Spain or Germany. One of the reasons appointed is the complexity associated with the Portuguese legal framework.

A feed-in mechanism, through two different frameworks, the Independent Power Producer law (IPP) and the simplified regime for electricity production through micro-production, is the main instrument for the promotion of RES in Portugal.

The definition of small energy producer has been established for long in the Portuguese legal framework. In 1944 it was included in the Law No. 2002, of December 26, as a reality to be taken into account in the legal framework. This definition of small energy producer changed mainly with the oil crisis, which had the merit of highlighting the finite character of some energy sources, and the necessity of diversifying and using all types of energy sources. The Decree-Law No. 189/88 (IPP) has set the norms on the activity of electric energy production by the different types of economic agents of the private and public sector, only including technical and safety restrictions.

Until the end of 2000 the cumulative PV installed capacity for electricity generation in Portugal was only about 1 MW. The domestic sector (off-grid systems) represented 52% of the total, the service sector (SOS systems, mobile network transmitters, car parking machines and others) represented 20%, grid connected systems represented 26% and the remaining 2% were related with R&D installations.

Figure 10 - New PV installed in 1984-2000



Source: Developed by the Author based on ADENE/INETI (2001)

Later, the Decree-Law No. 339-C/2001 introduced some changes, with the objective of establishing different remunerations according to the technology and exploration type, highlighting the PV as one of the renewable energy sources with the most potential in the medium range. One of the goals of this Decree was to create the necessary conditions for the development and implementation of exemplary projects using this kind of technology.

In 2002, the Decree-Law No. 68/2002 introduced the micro-production as an activity of generating electricity at low voltage, with the possibility of delivering electricity to the public electricity grid. This Decree produced a reduced impact and the Government designed a new programme for the promotion of micro-production.

First, through the Decree-Law No. 33-A/2005, which modifies the system of feed-in tariffs, establishing a new calculation system. The formula for calculating feed-in tariffs takes into account the technology, the environmental aspects and the inflation rate through the index of prices to the consumer. There are also some minimum and maximum tariffs, according to load variations on the grid. In 2007 the Decree-Law No. 225/2007 introduced new tariffs, considered new types of installation and simplified licensing procedures. Among all eligible technologies, PV benefits from the highest feed-in tariffs, which depend on the power at the interconnection point and whether systems are building integrated or not. Under this decree, the feed-in tariff is guaranteed for 15 years or 21GWh/MW (whatever is reached first) and varies according to the installed power and type of system (BIPV or non-BIPV). The national limit for PV is 150 MW and for BIPV is 50 MW. The Government has these limits as a goal to achieve until 2010, as part of the national strategy for energy. Currently the traditional IPP framework for PV is suspended because the licensed installations reached the limits defined. According to IEA-PVPS, in 2008 the Feed-in tariffs ranged from €0.354/kWh to €0.469/kWh for BIPV, and from €0.317 to €0.447 for non-BIPV, depending on the installed power.

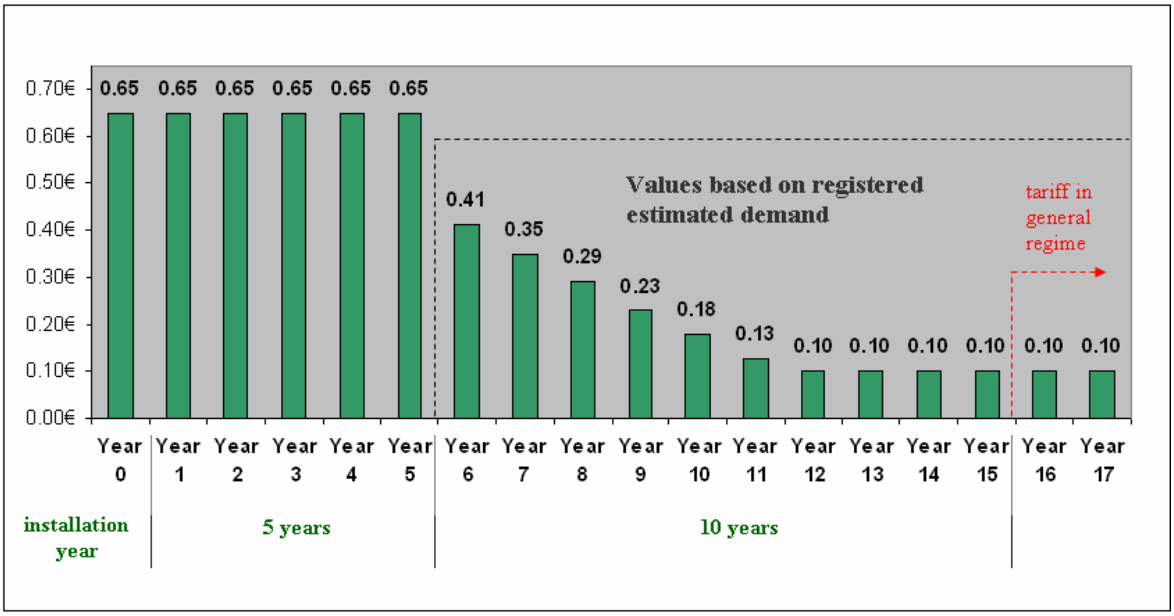
Secondly, and most important for decentralisation, the Decree-Law No. 363/2007 approved the simplified regime for electricity production through micro-production. This revolutionary Decree entered into force in 2008 and introduced transparency and simplicity to all this process. This decree establishes the micro-production registration system (SRM) that is an electronic platform where producers and the Executive share information. This decree also defines two payment regimes. The general regime is applied to most of the facilities with a maximum capacity of 5.75 kW and the second one, the special regime, is only applied to renewable energy sources, and the access to it requires, for individual producers, the existence of solar thermal collectors in the place of consumption and, for condominiums, the implementation of energy audits and correction of the measures identified. In the special regime, for individual producers the feed-in capacity is limited to 50% of the contracted capacity with the distributor, with a maximum of 3.68 kW. In the case of condominiums the limit is 3.68 kW regardless the contracted capacity.

All the producers that do not have access to the special regime are considered for the general regime. In that case, the feed-in tariff is the same as the selling price of electricity in that particular installation. For the special regime, and considering PV, the feed-in tariff is €0.650/kWh, for the first 5 years (excluding the installation year). After these five years and for 10 more years, the feed-in tariff will be the one applicable to the equivalent installations in the 1st day of January of the year of installation of those equivalent equipments. After these

15 years (5 years + 10 years) the feed-in tariff will be that defined for the general regime (see figure 11).

In the special regime, the tariff is only valid for the first 10 MW registered at national level, and for each additional 10 MW registered the feed-in tariff is reduced in 5% (currently the tariff is already 0.6175€/kWh). This estimation of tariff reduction can also be seen in figure 11. For instance, in year 6 it is expected that the tariff will be 0.41€/kWh, meaning that the estimated registered demand will be between 90 and 100 MW. This also means that the sooner the equipment is installed the better, since the first ones to register are the ones that will have the best tariff. Additionally the feed-in electricity sold is limited to 2.4 MWh per year and per installed kW.

Figure 11 - Tariffs evolution in the special regime assuming that the annual limit is reached



Source: Developed by the Author based on Renováveis na Hora (2009)

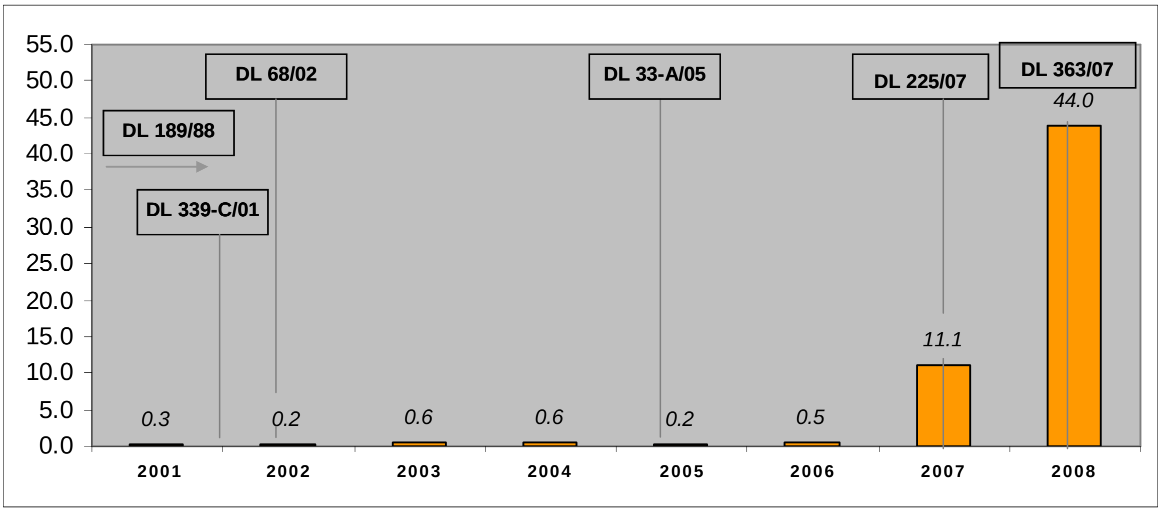
Finally it is important to refer that the national feed-in capacity registered in the special regime is limited to 10 MW in 2008, when this decree enters into force, and it will be increased 20% annually and successively. This means that the limit will be 12 MW in 2009, 14.4 MW in 2010 and so on.

According to the Ministry of Economy and Innovation the target defined until 2015 is to have 75,000 homes producing electricity with RES, with an estimated installed capacity of 165 MW (Ministry of Economics and Innovation, 2008). Additionally to this decree there are other measures implemented to boost the PV industry, namely financial and tax incentives. It is defined a VAT reduction rate from 20% to 12% on renewable equipment, an income tax reduction of 30% of the costs of those equipments up to a limit of € 796, and an exemption of income tax payment for micro production up to € 5,000 per year.

Also Portugal's sunny climate is a main driver for solar energy development. Sunshine in mainland Portugal varies between 1,800 and 3,100 hours per year and the total radiation varies from 140 to 170 kcal/cm^2. These climate conditions favour the photovoltaic conversion, with production outputs of 1,000 to 1,500 kWh per year and per installed kWp (Ministry of Economics and Innovation, 2007).

As seen before in figure 10, in the end of 2000 the PV cumulative installed capacity for electricity generation in Continental Portugal was only about 1 MW. In 2008 this value increased to 58.5 MW (see annex 5), with 41.4 GWh of electricity produced.

Figure 12 - New PV installed capacity in 2001-2008[8] - on-grid systems[9] (MWp)



Source: Developed by the Author based on Directorate-General for Energy and Geology, Portugal (2009)

In fact, the installed PV from 2001 to 2006 was very low, and only in 2007 and 2008 the market showed a booming trend. However one should use some caution analysing this trend

[8] Continental Portugal

[9] During all this analysis, for both Portugal and Germany, only will be considered on-grid systems. For these countries off-grid systems represent only small part of the total installed capacity and the real figures are difficult to obtain

because it includes the new big PV power stations in Serpa and Moura, which account for the majority of the installed capacity of both years.

In 2006 the market structure changed from off-grid systems to a structure strongly based in on-grid systems. This is due to the fact that the on-grid systems increased enormously while the off-grid systems slightly increased its cumulative installed capacity. In 2008 the on-grid systems represented over 95% of the total installed power (Paes, P.,S.,2009).

Portugal has been promoting big PV power stations in the south zone of the country called Alentejo. The Moura PV plant, with 45.6 MWp of installed power, is one of the largest centralised PV plants. It is situated in east Alentejo, one of the areas of Portugal with highest levels of solar radiation but also with high desertification. This project is important because it also contributed to the development of the PV panels industry, once a solar panel manufacturing facility was installed in this zone. The Serpa PV plant has 11 MWp of installed capacity. The power station's annual electricity generation is sufficient to supply 8.000 homes and farms in the region. According to the Ministry of Economics and Innovation (2007), in the Serpa PV plant "*the use of the "PowerLight PowerTracker System", accompanying the apparent movement of the sun, increases the system's efficiency by permitting more than 200 kWp to be controlled by a single motor/actuator with a rated power of only 0.5 kW*". Recently, in Ferreira do Alentejo, also in Alentejo, a new PV power plant was installed with a 12 MWp of installed capacity. Other important project includes the "Edifício Solar XXI", an energy efficient building in Portugal. This is an INETI (now called LNEG) project that associates an environmental optimisation strategy with the use of active and passive solar systems. The building has 96 m^2 of PV panels, with an installed power of 12 kWp and could avoid 8t of CO_2.

In the beginning of 2009, the installed solar industrial production capacity in Portugal was more than 120 MW/year in components of crystalline silicon, thin film and concentration PV. This production is mainly to export: 90% of the 250 million euros turnover of 2008 is from exports. It is expected a 500 million euros turnover for 2009. (Vasconcelos, S., 2009).

3.1.2. Solar Thermal in Portugal

The Cabinet Resolution No.169/2005 that defined the National Strategy for Energy was considered a truly fundamental document because it constitutes an important factor to increase the competitiveness of the Portuguese Economy, besides being a critical pillar for the national sustainable development.

In this Resolution it is assumed that higher energy consumption growth rates have been registered in the buildings and transportation sectors, not only because the behaviour of citizens is less disciplined than the behaviour of companies, but also because there is a lack of coherent and consensual energy and regional planning policies. So a change in the consumption habits and patterns was needed, with the implementation of policies that encourage the society to choose for the best energy and environmental options, through suitable economic instruments and through the reinforcement of access to information and education.

According to the Forum of Renewable Energies in Portugal, held in 2001, Portugal is one of the European countries with the best conditions for the solar thermal market, however it is still a market with a small dimension compared with other countries. One of the major conclusions of this event was that there is huge potential for market growth and there was a feasible target of achieving 2,800,000 m^2 of installed solar thermal collectors in 2010. The Forum also concluded that there is real potential for the implementation of 250,000 m^2/year, developing the necessary conditions to create 2,500 new jobs in this sector.

The major difficulties identified at that time in the development of this sector were the high initial investment, the poor credibility of these technologies, low awareness, constraints concerning building construction and lack of credible information about the sector.

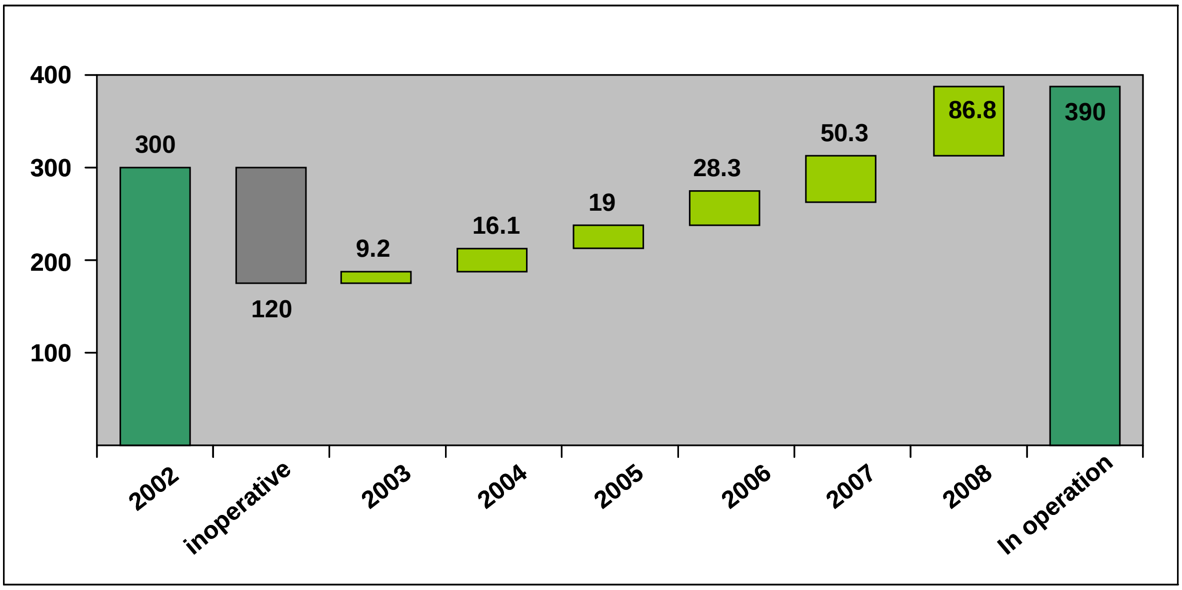
Later, in 2004, the revised objectives of the programme "Água Quente Solar para Portugal"[10] (AQSpP), like predicted in the E4 Programme, were included in the National Programme for Climate Change (PNAC). These objectives aimed to create a market of 150,000 m^2 of installed solar thermal collectors every year (revised to 13,000 m^2 for 2005 and 2006), with

[10] Solar Hot Water for Portugal

the purpose of having an installed and operating area of 1,000,000 m^2 of solar thermal collectors until 2010. In 2006, facing the bad results of the measures implemented the goals were revised once again. The new goal was to have 100,000 m^2 of installed solar thermal collectors every year during the period of 2007-2020, as a consequence of the new legislation for buildings in 2006/2007.

Eight years have passed since the E4 programme and it is now clear that the different targets defined for this period were unrealistic and the measures adopted were insufficient.

Figure 13 - Solar thermal cumulative area in operation - 2008 (1,000 m^2)



Source: ADENE (2009)

In 2002 there was an estimated cumulative installed area of solar thermal panels of 300,000 m^2, of which approximately 120,000 m^2 were inoperative. The estimated cumulative installed area at the end of 2008 was 390,000 m^2 and the target of 1,000,000 m^2 seems impossible to achieve until the end of 2010.

Until 2006 the most important measures defined to encourage the use of solar thermal were related with tax reductions and grants up to 40% of the total eligible cost, with a maximum limit, available under the programme of incentives for the modernisation of the economy - the PRIME programme. Also the certification of both the equipments and the installers played an important role in increasing the credibility of the sector. The development of the AQSpP as an observatory for solar thermal, aimed to provide credible information to promote and encourage this sector.

The 2008 National Plan for Energy Efficiency (PNAEE) sets different targets to be achieved until 2015. The new plan estimates that 1 out of 15 buildings will have solar thermal. To achieve this target several measures have been developed. Besides the increasing awareness of this type of technology, which naturally contributes to market growth, there are specific programmes to boost the market: the "Renove - Solar Térmico"[11] defines support to the renewal of the existent solar thermal collectors, while other programmes define IRS tax incentives of up to 30% of the investment in the new equipment installed. There are also specific programmes for specific segments such as condominiums, pools, and social housing, and it is mandatory to install solar thermal in new buildings.

The Decree-Law 80/2006, Rules for the thermal features behaviours of Buildings (RCCTE), which establishes the rules to be observed in the draft design of all housing buildings and service buildings without central air conditioning, is a very important law to promote solar thermal. This Rule exists in Portugal since 1990 and it was the first legal instrument to impose requirements of thermal comfort, either for heating, cooling or ventilation systems to guarantee air quality inside the buildings and to satisfy the needs of hot water without spending too much energy. However these Rules have been changing since their creation and according to this last change the installation of solar thermal collectors is mandatory whenever there is appropriate sun exposure. This instrument is applied to new buildings and to existing ones subject to major rehabilitation interventions and other specific conditions. Currently all the houses need an energy certification before being sold or rented. This can be considered as another bureaucratic administrative procedure to owners, however it is beneficial not only because it can highlight potential gains in energy consumption but also because it can be used in IRS.

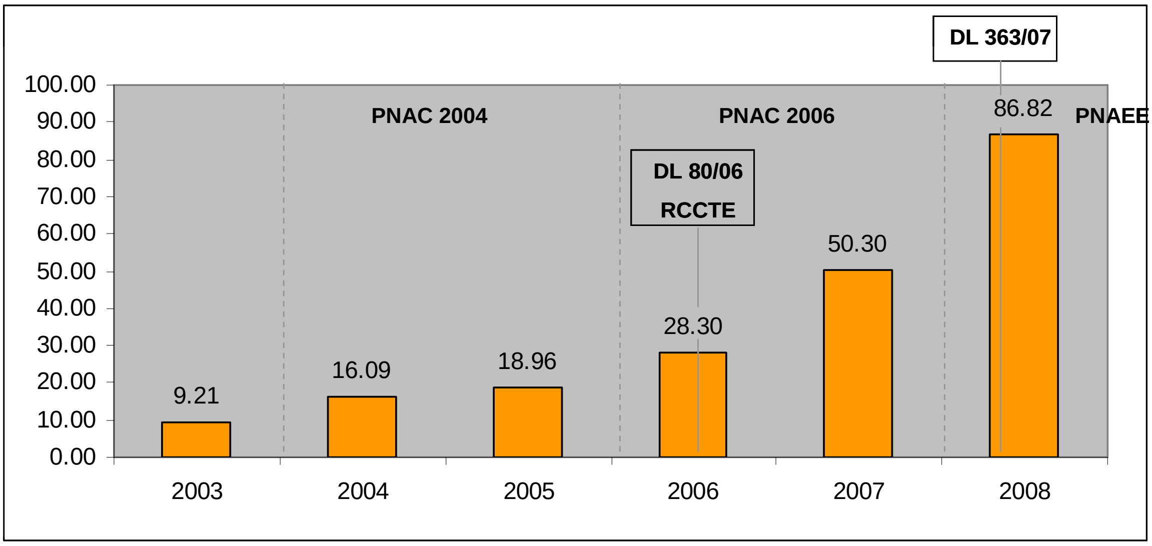
Another important instrument to promote solar thermal in Portugal is in fact the previously mentioned Decree-Law No. 363/2007. Although it is directed to PV sector, in the special regime, the access to it by individual producers requires the existence of solar thermal collectors in the place of consumption (see point 3.1.1). As PV market is booming due to this

[11] Renew - Solar Thermal

new legislation, it is likely that solar thermal will also be positively affected by this Decree. In the PNAEE it is defined that the impact of this Decree over the solar thermal will be of 1 m^2 for every kW installed.

Even if the original goals were unrealistic and the measures adopted were insufficient, it is clear that the market is growing. In 2008 the market grew more than 70% comparing with 2007, probably due to the effects of the implementation of the new RCCTE and the implementation of the Decree-Law No. 363/2007. Comparing 2008 with 2006 the market has tripled the installed area of solar thermal collectors.

Figure 14 - Installed new solar thermal collector area in 2003-2008 (1.000 m^2)



Source: Developed by the Author based on ADENE (2009)

Recently in March 2009, not only as a measure to promote the solar thermal market, but also as a measure to boost the national economy through this severe world crisis, the Ministry of Economy and Innovation developed an incentive programme for solar thermal. With this programme the Government contributes with 50% of the acquisition price of solar thermal collectors, up to a limit of approximately € 1,640, plus a 30% income tax reduction of the remaining value, with a limit of € 796.

3.2. Solar energy in Germany

In what concerns RE, Germany is one of the most developed countries in the World, and this sector has already achieved a capital importance in the German economical panorama.

Electricity generation is based primarily on coal and nuclear energy, with growing shares of natural gas and renewable sources. "*In 2002, Germany adopted a law phasing out nuclear energy. Under this law, each reactor is assigned a fixed amount of electricity it is allowed to generate. Once the electricity is produced the respective unit has to be switched off*". (European Renewable Energy Council, Germany review, 2008)

Germany is really trying to achieve an intelligent energy supply, ensuring that it is used efficiently. They have created an organisational model that favours the promotion of RES. For statistical reasons, the German Environmental Ministry, in collaboration with the Federal Ministry of Economics and the Federal Agricultural Ministry, "*has set up the Working Group on Renewable Energies - Statistics (AGEE-Stat), to ensure that all statistics and data relating to renewable energies are part of a comprehensive, up-to-date and coordinated system*" (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2008). It is an independent specialist body which includes experts from various and different Institutions.

In line with the climate change concerns, Germany has also developed very efficient control systems over pollution and energy efficiency. They constantly analyse the emissions avoided via the use of RES, amongst other important data, as well as fossil fuels saved via the use of RES. This kind of approach introduces transparency and objectivity to these analyses and eventually has a positive effect on public opinion and in the demand side of the RE markets.

In addition to these organisational issues, the German Government also supports RES through research and development, and offers a wide range of measures to encourage market development. Quotas, subsidies, reduced loans, and guaranteed feed-in tariffs are some of the attractive schemes adopted to promote RES. According to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008), with the adoption of these instruments, the Government incurs in costs as from a microeconomic viewpoint RE are still more expensive than conventional energy sources. However the Government defends that the beneficial effects of the promotion of RE overcome the implicit costs. They believe that these actions have a very positive influence on innovation, turnover and value-added in Germany, coupled with the creation of new jobs. Some Governmental research projects estimates indicate that around 245,000 jobs in Germany were attributable to RE sector in 2007, and over 50,000 to the solar energy sector. For 2020 there is a potential of around 400,000 employees in the renewables sector.

3.2.1. Photovoltaic in Germany

Regarding the promotion of RE in the production of electricity, Germany has been implementing several important measures for a long period of time.

The promotion of renewable electricity in the 80's was dominated by substantial R&D programmes of the Federal Ministry for Research and Technology. In the end of the 80's a market stimulation programme was introduced which called for the installation of 250 MW of wind power, creating the necessary conditions for the development and introduction of the Electricity Feed-in Act in 1991 (Held, A, *et a.l*, 2007).

According to the same source, this Act defined that the electricity utilities which operate a system for general supply were obliged to purchase the electricity generated from RE in their supply area and pay a percentage of the average historical electricity retail prices as feed-in tariffs, depending on the energy source. This Act presupposed a cap on the share of electricity from RES to prevent very uneven burdens for regional grid operators. It was also defined a voluntary commitment in favour of RE and the production of combined heat and power. So the Federal Government encouraged the electricity utilities to enter into voluntary commitments for additional measures to increase the proportion of electricity generation from RE and from the production of combined heat and power.

In the early 90's a grants programme called 1,000 roofs programme was the first step to a larger programme based on loans called 100,000 roofs programme. This programme was effective between 1999 and 2003, and it was designed to boost the German PV industry with the target of installing PV on 100,000 roofs with approximately 300 MW, and also not falling behind the level of Japanese development. So this was developed as a major support programme, as well as to attract private investment in manufacturing and application of PV systems.

"*The measure was implemented as low-interest loans that were provided by the states-owned bank Kreditanstalt für Wiederaufbau (KfW) for the construction and extension of photovoltaic power systems with a capacity of 1 kW or more*". Besides fulfilling all the established targets, this programme "*has successfully harnessed the fascination for PV technology*" and "*it has met with a good reception from economically high-end, ecologically-conscious segments of the population, who wanted to make a personal contribution to environmental and climate protection*" (REACT - Case study 8, 2004).

However, part of this programme success was also due to the guaranteed feed-in-tariffs defined in the 2000 Renewable Energy Sources Act (EEG[12]). This Act replaced the Electricity Feed-in Act, implementing some EU's recommendations, and brought substantial differences that stimulated industry even more. "*Under the new EEG, feed-in prices were no longer linked to electricity retail prices, but fixed for 20 years. The cap on the share of electricity from RES was abolished. Instead, the total amount of feed-in reimbursements was distributed evenly among all high voltage grid operators and equally among all electricity consumers there*"(Held, A, *et a.l*, 2007). Also it introduced the features of degression of tariffs supporting technology learning, decreasing the tariffs of new installations accordingly.

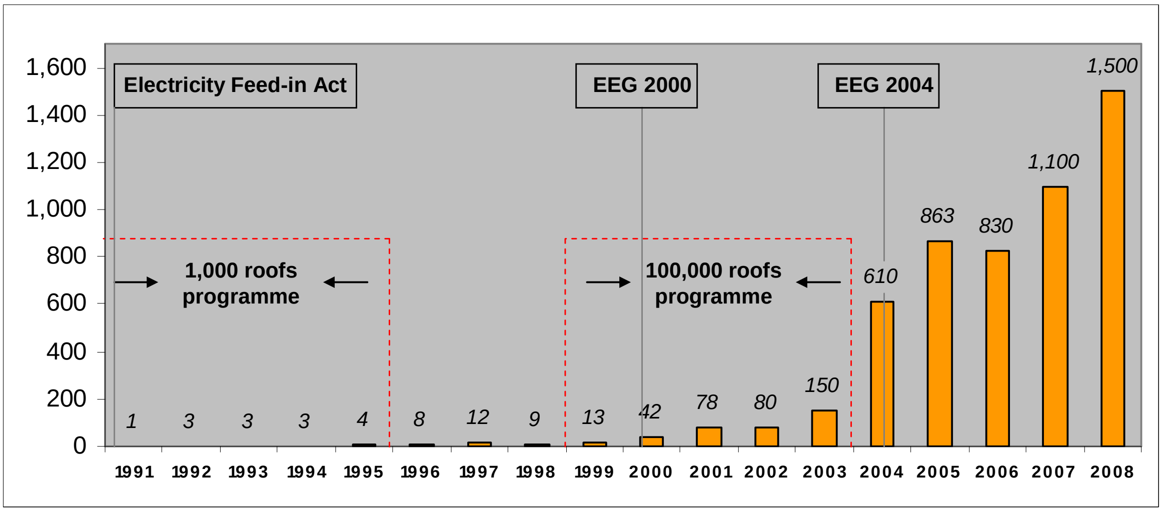
According to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2004), initially the compensation to be paid for electricity generated from solar radiation was at least 50.62 cent per kWh and degression was at least 5% annually. This EEG was very effective - from 2000 to 2004 the volume of electricity generated from RE more than doubled and brought about a nine-fold increase in electricity from PV systems in Germany.

In 2004 the EEG was amended. The new 2004 EEG included a detailed target for the share of renewables in electricity production of at least 12.5% in 2010 and at least 20% in 2020, underlining the importance of long-term stability of the German RES energy policy. The EEG amendment also assists the implementation of new EU directives. Furthermore, the tariffs were adjusted to better reflect the cost situation of renewable technologies. For PV, tariffs

[12] "Erneuerbare Energien-Gesetz"

rose in order to compensate the end of the 100,000 roofs programme. PV tariffs were also differentiated according to the application.

Figure 15 - New PV installed capacity in 1991-2008 - on-grid systems (MWp)



Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008;2009), renewable energy sources in figures, page 17, and Development of Renewable Energies in Germany in 2008, as at April 2009, page 21. Note: Data for the year 2008 is provisional.

This graph illustrates the booming of PV since 1991, and the influence of particular Government measures. If the 1,000 roofs programme and electricity feed-in act were residual contributions to the final cumulative installed capacity of electricity generation in 2008 of 5,311 MWp (see annex 5) that generated around 4,000 GWh of electricity, the 100,000 roofs programme combined with the 2000 EEG clearly mark the beginning of a successful Government RES energy policy.

In 2006 there was a decrease in PV installed capacity comparing it with the previous year, essentially because the demand surpassed the supply and some companies stocked out their equipments.

Recently, a new EEG was implemented. According to Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008), the new 2009 EEG introduced several changes and adaptations to the new developments occurred in the RES area and also to EU's recommendations, and inclusively aimed to increase the share of RES in electricity supply to at least 30 per cent by the year 2020 and to continuously increase that share thereafter.

This 2009 EEG also brought considerable differences in tariffs and degression schemes. The tariffs were updated to the current conditions of the markets. A tariff was introduced for a maximum capacity of 30 kW where the installation operator or a third party is using the electricity himself in the immediate vicinity of the producing installation. The bonuses for building integrated facilities (façade facilities) were abolished. The degression in the 2004 EEG ranged from 5 to 6.5%. In the 2009 EEG it varies from 8 to 10%, depending on the capacity, the year and the type of installation. A more detailed analysis of the 2009 EEG tariffs and degression is listed below.

Table 4 - Installations exclusively attached to or on top of a building or noise protection wall

Share of capacity	2009 EEG (ct./ kWh)
Up to 30 kW	43.01
30 kW - 100 kW	40.91
Over 100 kW	39.58
Over 1000 kW	33.00

Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008)

Table 5 - Fee payable when electricity produced is used within building/facility

Share of capacity	2009 EEG (ct./ kWh)
Up to 30 kW	25.01

Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008)

Degression:

- With a maximum capacity of 100 kW: 8% in 2010 and 9% from 2011 onwards
- With a capacity of over 100 kW: 10% in 2010 and 9% from 2011 onwards

Table 6 - Fee for freestanding facilities

Share of capacity	2009 EEG (ct./ kWh)
Irrespective share of capacity	31.94

Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008)

Degressions

- 10% in 2010 and 9% from 2011 onwards

In addition to the previous schemes, degression is to be either increased by 1 % point in the following calendar year when the capacity reaches more than 1500 MW in 2009, 1700 MW in 2010 and 1900 MW in 2011, or decreased by 1 % point in the following calendar year when the capacity remains below 1000 MW in 2009, 1100 MW in 2010 and 1200 MW in 2011.

According to the Bundesverband Solarwirtschaft (2009) the German PV industry has approximately 10,000 companies, of which around 130 are producers of cells, modules and other components. In the past 10 years the reduction of costs of PV installations was around 35%, and it is expected a decrease of around 85% of the costs for the period 1999-2020. In 2008, this industry employed 48,000 people and the sales to final customers were approximately €7 Billion. By the end of 2008, a total of 500,000 solar power systems had been installed on German roofs and the multi family houses, public and social buildings, farms, commercial plants with equipments of 10-100 kWp represented the biggest share of the market.

3.2.2. Solar Thermal in Germany

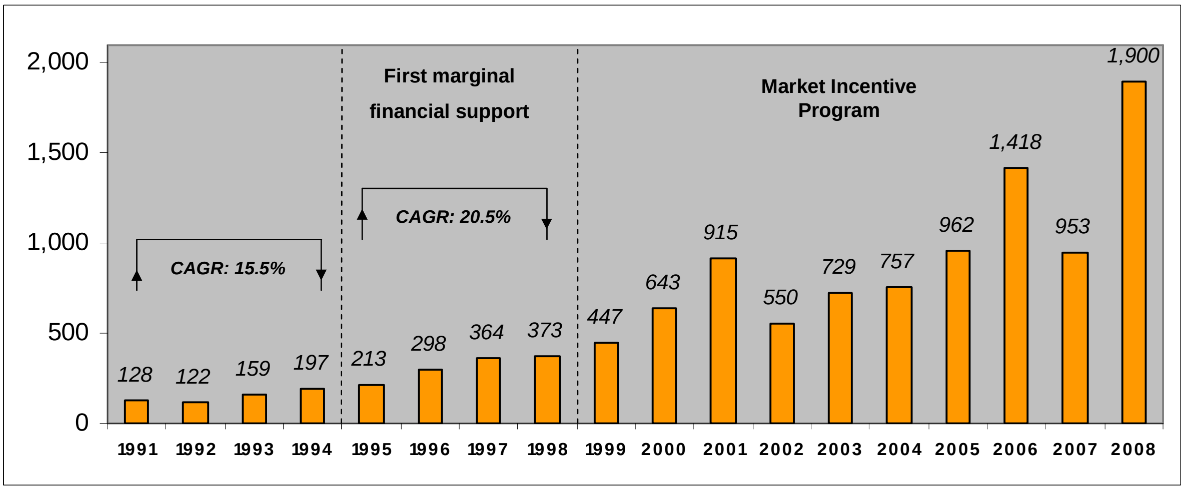
According to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008), the demand for heat in Germany is enormous: heat generation alone accounts for more than half of the total energy consumed in Germany. At present only 6.6 percent of heat generation comes from RE. The rest is obtained from fossil energy sources such as gas, oil and coal. Contrary to the strong supports given to PV market, the Government has been more conservative regarding solar thermal.

The first use of solar thermal technology for heat production occurred after the oil crisis of 70's. The increasing prices of fossil fuels created an opportunity for the less known and common energy sources. However solar thermal has never acquired a stable development. In the beginning of the 90's the heating sector was a "*niche market that was mainly dependent on local initiatives of associations or crafts people*" (REACT - Case study 3, 2004). However a major increase in usage did not occur until the late 90's, when effective federal and state subsidy programmes were established.

In 1995 the Federal Government introduced for the first time a marginal financial support scheme by subsidies for the period of 1995-1998. In 1999, the Market Incentive Program for RE was funded in connection with the ecological tax reform. The Market Incentive Program was a subsidy programme and the subsidies were paid through federal agencies (REACT - Case study 3, 2004). Although the programme was not conceived exclusively for solar thermal energy, the majority of its support went to this sector.

The next figure shows the evolution of the new solar thermal collectors installed area (1,000 m^2) by year, from 1991 until 2008, including references to the major measures such as the first marginal financial support and the market incentive programme.

Figure 16 - Installed new solar thermal collector area in 1991-2008 (1,000 m^2)



Source: Federal Ministry for the Environment, Nature conservation and nuclear safety (2008;2009), renewable energy sources in figures, page 18 and Development of Renewable Energies in Germany in 2008, as at April 2009, page 9. Note: Data for the year 2008 is provisional.

This analysis shows a clear connection between both programmes adopted by the Federal Government and the upward trend of solar thermal energy installed area. In fact, after the first marginal financial support of the Federal Government the market grew more than in the first years of the 90's. After the application of the market incentive programme, in 1999, the market grew even more. In 2008 the estimated solar thermal cumulative installed area operating in Germany was about 11,000,000 m^2 (see annex 6), equivalent to 7,700 MW_{th}[13] of installed capacity.

[13] To convert area into capacity, a conversion factor of $0.7 KW_{th}/m^2$ was used (IEA 95)

Since the adoption of these programmes, "*the market has shown a great dependence on subsidies, as shown by the economic slump of 2002, when less than expected subsidy funding was available. With the improvement of the situation in 2003, and an increase in subsidies, the market grew up again*"(REACT - Case study 3, 2004).

However there are more than just subsidies to stimulate the market. There have been special initiatives supported by a federally sponsored foundation - "Solar-na-klar", that raised significant public interest for solar thermal appliances. Another initiative was the marketing campaign - "Initiative Solarwärme Plus", mainly concentrating on informing local crafts people. Additionally there are some specialised homepages concerned with solar thermal energy.

Another important stimulus for the development of solar thermal energy market has been the quality and technological issues. The quality of products and services, qualification, technical features and reliable and efficient technologies were important drivers in the beginning of the market growth, but nowadays they are mainly a marketing issue since they are common and necessary criteria for the success of this entire sector. In addition, since 2004 all appliances have to ensure some efficiency standards as a precondition for public subsidies, which have to be fulfilled by all manufacturers (REACT - Case study 3, 2004).

Even if the market incentive programme has not in the past increased the share of RE to the desired extent, it has nevertheless been very successful. According to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008; 2009), since its launch the programme has provided financial support amounting to 912 million Euro, which has triggered investments of 7,700 million Euro (as at May 2008). During 2008 this programme received a total of 170,204 applications for support for solar collectors.

Although the Federal Government developed several measures to stimulate the solar thermal market, the measures adopted for the PV market were much more intense. So, the dramatically rising interest in PV-roofs as an alternative to solar thermal roofs, with better economical conditions and expected return on investment, was in fact one of the major obstacles for a further development of solar thermal energy in Germany. To overcome these obstacles and to develop a stable and clear statutory framework, on the 1st of January 2009 the Renewable Energies Heat Act came into force.

The Heat Act stipulates that by 2020, 14% of Germany's heat must come from RE. This act is based on three main aspects: the obligation to use renewables, financial support and heat grids.

According to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008), all owners of newly erected buildings must use RE, whether private individuals, the state or businesses. All forms of renewables, or combinations of them, can be used. Those who do not wish to use RE can take other climate change mitigation measures such as improving the insulation of their buildings, obtaining heat from district heating systems or using heat from combined heat and power generation. Regarding the financial support, the use of RE will continue to be financially supported. The government will inject more money into the existing market incentive programme, increasing funding for this support instrument to as much as 500 million € per year, introducing better planning certainty for investors. Finally this Act makes it easier for heat grids to be extended.

This Act regards several RE, obviously including solar thermal. Building owners can cover a certain proportion of their heat needs from solar energy. The Act stipulates the size of the collector in relation to the type of building. In a building containing no more than two dwellings the collector size must be at least $0.04m^2$ per m^2 of heated floor space. For buildings with more than two dwellings the collector must be at least $0.03\ m^2$ per m^2 of heated floor space. Owners of all other types of building, notably non-residential buildings, must cover at least 15 percent of their heat needs if they opt to use solar radiation.

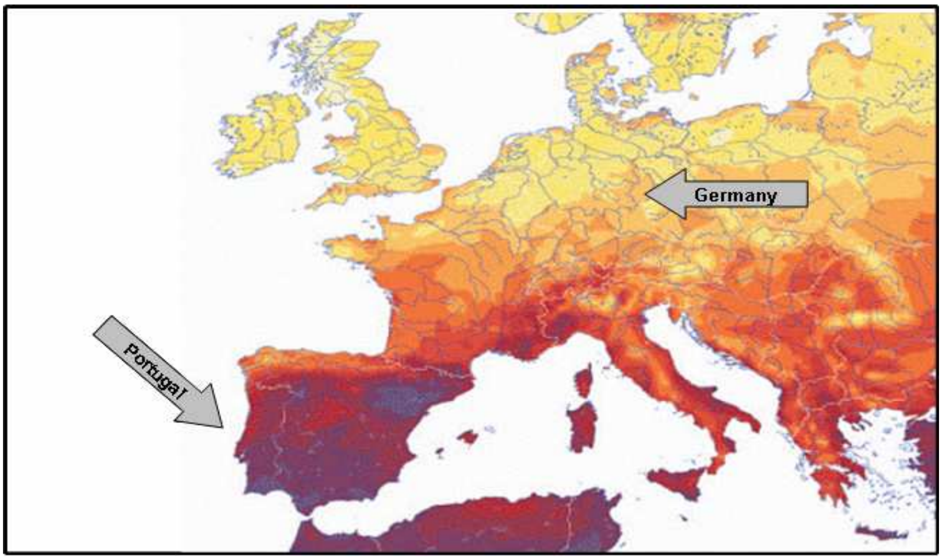
According to the Bundesverband Solarwirtschaft (2009) the German solar thermal industry has approximately 5,000 companies, of which around 100 are producers of collectors, storage units and components. Between 1990 and 2008 the cost reduction of solar thermal installations was around 40% and a decrease of around 66% of the costs for the period of 1990 to 2020 is expected. In 2008, the sales to final customers were approximately €1.7 billion.

3.3. Comparing Portugal with Germany

In this chapter a comparative analysis between Portugal and Germany will be performed, with special emphasis on the concrete differences between both countries and in factors that could eventually help to understand those differences. This comparison will summarise the course and policies adopted by both countries in order to conclude about the real impact of each policy on the solar energy development. Being Germany one of the strongest countries in the world concerning solar energy development, the idea is to consider it as a best practice for industry in order to allow, in the last chapter of this dissertation, to achieve some considerations and proposals for the future development of solar industry in Portugal, taking into account not only the successful case of Germany, but also Portugal's specific conditions as well as current and future industry trends.

In absolute terms the cumulative installed capacity of PV energy in Portugal at the end of 2008, has been achieved by Germany in 1999, even before the implementation of the EEG in 2000. Does this mean that Portugal is 10 years behind Germany? Well, the question is not so simple, since Germany is a much larger and more populous country than Portugal, with a very strong economy and a highly developed industrial base, therefore making it ungrateful to compare the development of both countries. On the other hand, Portugal has much more natural conditions for installation of solar energy systems. The next figure illustrates well the differences in solar radiation between these two countries:

Figure 17 - Solar Radiation in Europe



Source: Portal das Energias Renováveis

One of the first conclusions to be drawn from all the data analysed so far, is that Germany since the 90's has shown a great dynamism on the promotion of RE and on solar energy in particular. Measures such as the implementation of the Electricity Feed-in Act in 1991 and the 1,000 roofs programme were the starting point for a truly revolutionary policy concerning PV solar energy. In Portugal during the 90's the scenery was substantially different. To get an idea of the difference between the two countries, in 2000, Portugal had a cumulative installed capacity of around 1 MWp to about 100 MWp in Germany. This means that Germany had a cumulative installed capacity 100 times higher than Portugal, when German population is only about 8 times higher[14].

It was precisely in 2000 that the revolutionary EEG came into force in Germany, which definitely boosted the implementation of RE in this country, including PV solar energy. The annual growth since 2000 has been much higher than in Portugal (far above 100 times) and only in 2007 the Portuguese installed capacity became again 100 times lower than the German one. However, in that year the cumulative installed capacity in these countries already differed more than 260 times, as a result of the strong PV development in Germany in previous years following the successful policies implemented. In other words, from 2000 to 2007 the installed capacity in Germany and Portugal diverged more than it had so far. It is expected that in the future, also following the reformulation of the legal framework and due to the several measures implemented by the Portuguese government, this difference decreases. In fact in 2008, this cumulative difference decreased to about 91 times (cumulative installed capacity of 58.5 MWp in Portugal against a cumulative installed capacity of 5,311 MWp in Germany).

In 2007 the cumulative installed capacity per 1,000 inhabitants in Portugal was 1.37 kWp and 46.36 kWp in Germany. In 2008 this value rose to 5.52 kWp in Portugal, representing an increase of about 4 times (mostly as a result of the construction of PV power stations in Alentejo). In the case of Germany for 2008, the provisional data appoints to 64.61 kWp, representing an increase of about 1.4 times.

[14] According to Eurostat, in 2008 the population of Portugal was approximately of 10.6 million people and the population of Germany was approximately of 82.2 million people. Even if there are variations throughout the years, in this analysis these will be the figures used in several energy ratios for comparison purposes.

One first big difference between both countries is the complexity of the general legal framework for PV. In Germany, under one only act (2009 EEG), all the situations are covered from the smallest installations to the biggest solar power plants. In addition, the tariffs and the degressions are clear and previously defined, making it easy to understand and to interpret all possible solutions. Unlike the German situation, in Portugal the legal framework is far more complex. Even if the main instrument for promoting RES is a feed-in system for all the situations, there are two different frameworks - the traditional IPP for higher installed rated power and the micro-production scheme, for lower installed rated power installations - that make the understanding of each scheme and the complementarity of both schemes much more complex.

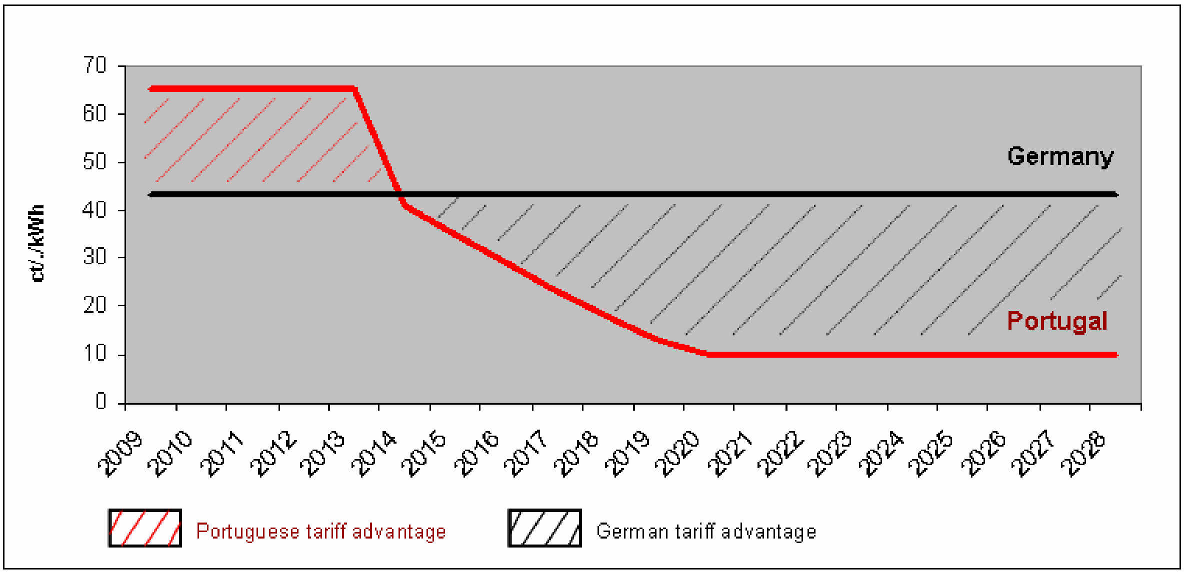
In the traditional IPP, is difficult to determine the tariffs and all the conditions required, basically because they depend on several variables and complex formulas. Also the limits defined for the IPP framework at a national level are low, lacking ambition, and that is why the licensing of new installations is currently suspended. This suspension compromises the future development of PV in Portugal. In Portugal the tariff is subsidized for 15 years or 21GWh/MW, while in Germany the tariff is fixed for 20 years without a cap.

The micro-production scheme is easier to understand, however it contains many limitations that eventually will confuse the interested agents. Regarding the dates of implementation of micro-production, only in 2008 Portugal truly adopted the feed-in system with competitive conditions for micro-production, while Germany has already been using successfully this instrument since 2000. The current systems differ in some crucial issues.

The Portuguese law guarantees a subsidised tariff for a period of 15 years after installation, however for the micro-production case it will decrease from the sixth year on, being estimated that in the 12^{th} year the tariff is equivalent to the general regime tariff, assuming that the annual limits are constantly achieved. In other words, it is expected that for 12 years the tariff is higher than the electricity distributor's price. In Germany the initial tariff is guaranteed for a period of 20 years.

Figure 19 represents an estimate based on the current assumption of a theoretical comparison of feed-in tariffs in Portugal and Germany, over a period of 20 years, for a system installed on a house's roof in 2008 and beginning to produce electricity in 2009[15]. This estimate takes into account the premises of tariffs reduction included in the official documents of the Portuguese Government, where it is assumed that the maximum connection power is achieved annually.

Figure 18 - Feed-in tariffs comparison between Portugal and Germany



Source: Developed by the Author

From this comparison's analysis one concludes that the tariff is more favourable in Portugal for the first 5 years after installation, while kept fixed. However, at the end of the sixth year, when it starts to be defined by variable factors, it becomes unfavourable in comparison with German tariff in that year. In the sixth year, the estimated tariff in Portugal will be 41 cents per kWh, while in Germany it will be 43.01 cents per kWh, as this is the fixed value in 2009 for this type of installation and for a period of 20 years. However, it should be taken into account that this situation can be substantially different and more favourable for Portuguese installations, if the registration estimates are under the maximum limits defined.

The truth is that the tariff's term is critical to the success of this mechanism. So, the implied stability in the 20 years term of fixed tariff, included in German system, also leads to a stable investment climate, promoting the micro-producers' confidence for the installation of more technologically advanced systems. On the other hand, it also creates the suitable conditions

15 In the case of Portugal it was considered the tariff in force for PV during all 2008 and in the beginning of 2009 of 65 cents per kWh. However, currently the tariff in force for PV is already 61.75 cents per kWh.

for the strong development of the industry, promoting the investors' confidence to invest more in R&D.

For example, in the purely theoretical field, if we consider the above mentioned tariffs and an installation producing 5,000 kWh per year for 20 years, also assuming that there is no cost with equipment maintenance and a discount rate of 3%, we will have the following total discounted cash flows (not including the investment in equipment) for Portugal and Germany according to current legislation (see annex 10):

∑ Portugal discounted Cash-flow = € 24,002
∑ Germany discounted Cash-flow = € 31,994

Theoretically, the situation in Germany will be more favourable than in Portugal due to the difference of total discounted cash flows. However, a comparison at this level is not straightforward for the reasons given below.

Considering the average prices of the equipment in Portugal and Germany, the average investment will be lower in Germany when compared to Portugal. However, it is also true that for the production of 5,000 kWh the equipment should be more efficient or with greater production capacity in Germany due to worse conditions of solar radiation and it will therefore involve a greater investment. On the other hand, in accordance with current legislation in Portugal, there is the possibility that the consumer also has to install solar thermal collectors. In this case, the investment for installation in Portugal will certainly be far more costly than the installation for the production of the same electricity in Germany. It is also known that, financially, the sooner we receive the financial benefits, the better is for project profitability. Accordingly, considering that the first five years of investment in Portugal are paid with a tariff much higher than in Germany, in terms of project finance the situation may be more favourable in Portugal.

The conclusion from such a comparison is not that the investment will be more profitable in Portugal than in Germany, or vice versa. Both systems and the characteristics of the countries have comparative advantages, being the Portuguese system more supportive of a high tariffs scheme in the initial period, while the German system is more supportive of a long term scheme. However, when compared with the Portuguese system, the German system seems to be more consistent and financially credible to the consumer, for different reasons other than the longer-term perspective.

The limits for application of subsidised tariffs are substantially different in the two countries. The German system is segmented into different options for electricity production through solar energy and the limit included in the most unfavourable situation is set for equipments up to 30 kW. In the Portuguese case, and for the micro-production, besides having a substantially lower limit in most situations (3.68 kW), there is also an annual production limit of 2.4 MWh/year for each kW installed. Thus, in theory, the annual limit of electricity production through solar energy, by earning subsidised tariffs for each micro-producer, is 8,832 kWh/year[16] in Portugal. Moreover, the tariff will be gradually reduced by 5% whenever 10 MW registrations are reached. That is, for every 10 MW of additional power registered the tariff will be reduced by 5%. Portuguese market has still another limit that is 10 MW from which the subsidised tariff will not be paid. This limit will increase 20% every year. In 2009, as this is the second year since the entry into force of the decree, this limit is already 12 MW. In practice, in 2009 the first 10 MW registered will be paid with the maximum tariff at that time, from 10 MW to 12 MW it will be paid with the maximum tariff less 5% of its value and from 12 MW on (annual limit for payment of subsidised tariff in 2009) it will be paid with the general tariff without subsidies.

The German system is defined by a degression system and there is no limit set for not having subsidised tariffs. These degressions vary from 8% to 10% depending on the maximum capacity of the different systems and the year in question. However there are limits to increase or reduce the degressions. For example, if the national capacity achieves 1,500 MW in 2009, the foreseen degression will be increased by 1%. However, if this capacity in 2009 remains below 1,000 MW then the degression will be reduced by 1%. These limits are different depending on the years.

Also in this field the German system seems to be more attractive to investors. Despite the fact that degressions currently are higher than in the past, the tariff set in the 1st year is never in question for 20 years. These degressions are only applied to the reference tariffs of new equipments installed, not affecting installations already in production. This measure serves

[16] 3.68 kW x 2.4 MWh = 8,832 kWh/year

only to apply the concept of technology learning, adjusting yearly the market to the expected technological development, encouraging continuously efficiency improvements and cost reductions for new plants.

Table 7 - Summary of the main features of PV market in Portugal and Germany

Criteria	Portugal	Germany
Sector development:	- Strongest sector development since 2006	- Strong and consistent growth since 1999
Important legislation:	- Decree-Law 189/88 - Decree-Law 68/2002 - Decree-Law 225/2007 - Decree-Law 363/2007	- Electricity Feed Act 1991 (strEG) - Renewable Energy Sources Act 2000 (EEG) - Renewable Energy Sources Act 2004 (EEG) - Renewable Energy Sources Act 2009 (EEG)
Type of current system:	- Feed-in system (IPP and micro-production)	- Feed-in system (unique framework)
Main characteristics of the system:	**IPP** - Tariff is subsidised for 15 years or 21GWh/MW **Micro-Production (special regime)** - Tariff is fixed for the first 5 years (excluding the installation year) - Tariff will decrease 5% for each block of 10 MW of new installations - The capacity limit for the equipments is 3.68kW, and the yearly production is limited to 2.4 MWh for each kW - The yearly limit to access the subsidised tariff is limited to 12MW in 2009. This limit will increase 20% each year	- Tariff is subsidised for 20 years - Tariff is fixed for 20 years - Tariff degressions for new installations range from 8% to 10% - The capacity limit for the equipments is 30kW, in the worst case
Current Feed-in tariffs (As of July 2009)	**IPP** - From € 0.3170/kWh to € 0.4690/kWh depending on the share capacity and the type of installation (Approximate values based on 2008 tariffs appointed by IEA-PVPS) **Micro-Production (special regime)** - Tariff of an installation with a limit of 3.68kW : € 0.6175/kWh	- From € 0.2501/kWh to € 0.4301/kWh depending on the share capacity and the type of installation - Tariff of an installation on the top of a building with a limit of 30kW : € 0.4301/kWh
Main additional support mechanisms	- Tax deductions - Soft loans - Investment incentives - Subsidies	- Tax deductions - Soft loans - Investment incentives - Subsidies
Cumulative installed grid connected capacity:	- Year 2000: 1MWp - Year 2007: 14.5MWp - Year 2008: 58.5MWp	- Year 2000: 100MWp - Year 2007: 3,811MWp - Year 2008: 5,311MWp
Cumulative installed grid connected capacity *per capita* :	- Year 2007: 1.37kWp/per 1,000 inhabitants - Year 2008: 5.52kWp/per 1,000 inhabitants	- Year 2007: 46.36kWp/per 1,000 inhabitants - Year 2008: 64.61kWp/per 1,000 inhabitants
Contribution to electricity generation:	- Year 2007: 23.6 GWh - Year 2008: 41.4 GWh	- Year 2007: 3,075 GWh - Year 2008: 4,000 GWh
Electricity prices charged to final consumers without taxes (source: Eurostat)	- Year 2007 Medium size holdholds: € 0.1420/kWh Medium size industries: € 0.0860/kWh - Year 2008 Medium size holdholds: € 0.1410/kWh Medium size industries: € 0.0895/kWh	- Year 2007 Medium size holdholds: € 0.1433/kWh Medium size industries: € 0.0946/kWh - Year 2008 Medium size holdholds: € 0.1299/kWh Medium size industries: € 0.0929/kWh

Source: Developed by the Author

The Portuguese system is different because it sets a limit to the national production. Indeed, despite the fact that the licensing and registration of new installations is much simplified by the online SRM, the limitation of power registered is pointed out as one of the problems of the Portuguese micro-production system. Due to this limit, any interested party is led to run for obtaining the maximum subsidised tariff. The opening of a tender was set on a monthly basis for the allocation of licences for micro-production, with a limit of 2 MW. When this limit is reached the online system is closed, allowing no more registrations. QUERCUS criticises this system arguing that it favours corporate entities that have many online computers to perform the registrations, damaging domestic consumers who have less capacity to register their installations within the limits. For example, in 2008 there were tenders that lasted no more than 2 hours until all available power was registered.

But a successful policy to promote the use of RE, including solar PV, does not work only with micro-production laws. For a real dynamization of these markets there has to be a well-balanced policy mix, and here both Germany and Portugal are good examples of this practice. Tax deductions on RES investments, soft loans, investment incentives, and subsidies are part of the several additional instruments used by both countries. In the case of Germany there were even parallel and specific programmes for solar PV such as the 100,000 roofs programme.

Regarding solar thermal energy the difference in development between Portugal and Germany is also very significant.

As a result of the huge demand for heat in German market, since the 90's, specific programmes have been developed for promoting this industry. However, in Portugal the concerted development of solar thermal only took place in the 21st century.

In 2002 Portugal had a ratio of 17 m^2 of solar collectors installed per 1,000 inhabitants, while in Germany this ratio was of 57.8m^2 per 1,000 inhabitants. In 2007 those figures increased to 28.6m^2 per 1,000 inhabitants in Portugal and 116.4m^2 per 1,000 inhabitants in Germany. In 2008 and as a result of the recent measures adopted by the Portuguese government, 86,800m^2 of new solar panels were installed, which is the largest ever installed area in Portugal, therefore it is expected that this number will increase further over the next years. As a result of this increase, in 2008, the ratio of solar thermal collectors installed per 1,000 inhabitants also increased to 36.8m^2. In Germany this ration increased to 133.8 m^2.

In Portugal, since the development of the PNAC in 2004 and its revision in 2006, a series of measures have been defined to promote endogenous energies, which include solar thermal energy. The RCCTE is a major instrument for the promotion of solar thermal and the Decree-Law 363/07 on micro-production of electricity has also helped to boost the solar thermal market. More recently the PNAEE has established concrete measures to achieve the defined goals. However, it is the mix between current law, benefits and incentives to purchase such equipments along with the specific programmes for this type of technology that make all the difference. Moreover, that has also been the success of German policy in this field.

One of the most visible programmes in Portugal, which is in force up to the end of 2009, is the turn key system entitled "Programa solar térmico 2009"[17]. This programme includes a series of benefits and incentives for solar thermal energy, such as a support by the Government of up to 50% of the equipment acquisition cost, tax incentives associated with the investment by consumers, loans on favourable terms, among other conditions. The programme has a high potential not only for the excellent conditions offered to the consumers, but also for its simplicity and for being widely promoted in the media, having even an exclusively dedicated site (see annex 7). This programme comes as a measure to boost solar thermal market when the world is being strongly affected by the current crisis. In the first four months of the programme implementation, 40,000 m^2 were installed. However, this programme is being criticised because only includes some types of housing and some institutions and sports associations, and because it excludes some installers in the industry. Other programmes like "Renove – Solar Térmico" are very important for the development of these markets, but it is the mix of all these actions that will make the difference in the future.

Germany has been promoting the development of solar thermal energy for a long time, mainly as a result of the huge heat demand in the country. Since the 90's, government has developed specific support programmes to the sector. The most significant programme of this governmental policy was the market incentive programme implemented since 1999, which decisively boosted the solar thermal sector.

[17] 2009 solar thermal programme

To get an idea of the difference in implementation of solar thermal energy between the two countries, in absolute terms the cumulative total area of operating solar collectors installed in Portugal at the end of 2008 (390,000m^2) has been reached in Germany in 1991. In 1999 the annual installed area of Germany for that year (447,000m^2) was already higher than the cumulative total area of solar thermal collectors installed in Portugal at the end of 2008. As in the PV sector, it will be ungrateful to compare these two realities in countries with very different dimensions, however one can agree that these comparisons serve mainly to give an idea of the development stage of a country with worse natural conditions than Portugal, even more when it is known that in Portugal the systems installed and to be installed will be mostly thermosiphon systems, requiring lower investment compared with the forced circulation systems, much used in Germany. The conclusion is that natural resources alone do not justify the development of RE and the policies adopted have a key role in this development.

One important issue when analysing the development of solar energy as a whole, is a possible gap in the development of PV solar energy comparing with the solar thermal as a result of the different policies adopted. In Portugal a balance between both was achieved, by establishing a system of tariffs that substantially improved the expected return on investment in PV solar energy and therefore its attractiveness, but also in solar thermal energy through the micro-production law that require, in some cases, the installation of solar thermal collectors. Current legislation regarding thermal conditions of new houses construction also includes the requirement for installation of solar thermal collectors, promoting the dynamism of the sector, as well as the specific support programmes like the one currently in force for 2009.

In Germany, the incentive systems for both sectors are different and, although there is already a major development of solar thermal energy, there is a perception that something more can be done to promote this sector, taking especially into account the huge demand for heat. The Renewable Energies Heat Act appears as an instrument to promote RE technologies for heat production, where solar thermal is included, and some of its measures are already foreseen in Portuguese law.

Another important issue for the credibility and affirmation of solar energy is related with the inherent quality in the sector. Both for solar PV or solar thermal, the implicit quality of equipment and installers is essential. In Portugal, recently, there was still a negative idea of solar thermal in particular as its credibility was negatively affected by the poor quality of services provided. Currently, this type of technology has gained credibility through certification of equipment and installers, so the suspicion by consumers on these solutions has fallen. However, the concern with certification has begun earlier in Germany than in Portugal, which can also be a reason for the different stages of development. Some argue that this may indeed be a justification for differences between both countries, along with the fact that, in Portugal, sales companies are making prices higher than in other countries, which also discourages further investment

Table 8 - Summary of the main features of Solar Thermal market in Portugal and Germany

Criteria	Portugal	Germany
Sector development:	- Consistent growth since 2002. Strongest growth since 2006	- Strong and consistent growth since 1992 with some slumps in 2002 and 2007
Important legislation:	- Decree-Law 80/2006 (RCCTE) - Decree-Law 363/2007	- Renewable Energy Heat Act 2008 (EEW)
Important specific and general programmes:	- PNAC 2004 - PNAC 2006 - PNAEE 2008 - Incentive programme of 2009	- First Marginal Financial support (1995) - Market Incentive Program (since 1999)
Main additional support mechanisms:	- Tax deductions - Soft loans - Investment incentives - Subsidies	- Tax deductions - Soft loans - Investment incentives - Subsidies
Total estimated cumulative installed capacity:	- Year 2000: Not available - Year 2007: 303,200 m^2 - Year 2008: 390,000 m^2 Note: Only considered equipments in operation	- Year 2000: 3,284,000 m^2 - Year 2007: 9,568,000 m^2 - Year 2008: 11,000,000 m^2 Note: The data for 2008 is provisional and refers only to equipments in operation. Data for 2007 includes inoperative equipments
Total estimated cumulative installed capacity per capita:	- Year 2007: 28.6m^2/per 1,000 inhabitants - Year 2008: 36.8m^2/per 1,000 inhabitants	- Year 2007: 116.4m^2/per 1,000 inhabitants - Year 2008: 133.8m^2/per 1,000 inhabitants

Source: Developed by the Author

A final issue is related with cultural and educational differences of both populations. Germany has been a revolutionary country in terms of education and environmental policy, so this feature is naturally reflected in the development of the use of RES. This typical feature of the northern European countries has been reflected for a long time in Germany, being more recent in southern countries like Portugal. Hence there is a greater sensitivity to solar energy, in Germany when compared to Portugal. This sensitivity combined with a number of other factors, is reflected in the education and culture of citizens, increasing their predisposition to use these energy sources as well as to other issues related to sustainability and climate change. This conclusion was empirically confirmed by the Author through the contact with German citizens and institutions, during his stay in Germany for an academic semester.

Even in what concerns urbanism, the situations are substantially different, not only for the mentioned predisposition and sensitivity of inhabitants and licensing authorities, but also for the urban features of the countries. Germany was heavily affected by the devastation of the World War II and, having most of its cities destroyed, and it was geographically divided to be reunited again later. The existing architecture is mostly post-war, so the inclusion of solar energy equipments, either on roofs or in facades of buildings, is not very controversial. In Portugal the situation is very different. The Portuguese Architecture includes many old and historic buildings, making it more difficult and with higher costs the inclusion of RE systems such as solar energy. On the other hand, both architects and licensing authorities, in an effort to preserve the architectural heritage or purely for reasons of urban aesthetics, have been reluctant to install solar panels in buildings. This is one of the major challenges of solar thermal development in Portugal.

4. Strategies for Solar Energy in Portugal

4.1. Strategic framework

Taking into account all the analysis developed so far, the goal for this last chapter is to briefly summarise the main features of the Portuguese solar market, using a PESTEL[18] analysis, in order to clearly and objectively identify the areas for future improvement and establish, whenever possible, a set of concrete proposals for those areas that could most benefit the development of solar energy in Portugal.

As seen throughout this document, in political terms there are several reasons supporting the development of solar energy in Portugal. On one hand, concerning RES, there is a strong influence of the policies proposed by EU on national policies. On the other hand, this influence has been well adapted to the Portuguese framework, mainly since the 21st century and there is now a major commitment by the Government with the development and promotion of RE, although with great distinction between the different technologies. This commitment is also reflected in an appropriate policy mix, directed to different situations. For solar energy in particular, the goals and measures adopted could be more ambitious and challenging in order to explore to the most the growth potential of this energy source. The current government has absolute majority in parliament, which allows great political stability on conducting national policies. However, 2009 is an exceptional year in Portugal because 3 elections are scheduled, namely to the European Parliament, Legislative and Municipal elections, which may change the current political overview and will certainly influence the decision making process for 2009.

In economic and social terms, some subjects should be highlighted. The development of solar energy is still in an embryonic stage, representing a minority percentage of the energy mix and with a reduced importance in national economy. However, the development of isolated projects such as solar photovoltaic power plants in Alentejo, are important sources of foreign investment in Portugal, which if well explored may have a significant impact in the local economy. In the economic sphere the present situation is particularly worrying for all sectors due to the global crisis. Also the fact that Portugal has a low GDP per capita compared to

[18] PESTEL analysis - Political, Economic, Social, Technological, Environmental and Legal

other EU countries along with major differences in the income distribution, especially between the country's interior and coast, not only reduce the economic capacity of Portuguese consumers but also create greater difficulties in market segmentation. However, the Government and companies' effort to promote solar energy has increased the visibility of these technologies, even if that visibility still doesn't have the necessary correspondence to the amount of equipments installed. That visibility has been achieved, among other factors, by increasing advertising and social events, such as presentations, forums and conferences.

Taking into account the strong dynamics of technological developments and the development potential of the global solar industry, in Portugal the R&D spendings are still small compared to other markets. It is true that there are some R&D projects that became marketable products, but these are the exception rather than the rule.

Portugal can be considered a privileged country regarding RE since, contrary to what can be thought, it has a great availability of resources. The conditions for solar energy development in Portugal are very good and this becomes even more important when knowing that the development of solar energy is a strong assumption of energy efficiency and climate change mitigation's plans, both on national and European level. *I. e.*, not only Portugal has the opportunity to develop the exploration of a resource that it is widely available, but by doing that it will also make a strong contribution to the success of energy efficiency and climate change mitigation's plans.

Regarding legislation, the situation is also favourable to solar energy development. The legal framework is stable and comprehensive, not only as a result of the new law regulating micro-production and feed-in system, but also by the implementation of other regulations, such as RCCTE that promote energy efficiency and the use of RE. Besides current regulations, there are still other incentives for solar energy use, and tax incentives are one of the most important ones. However, this situation can still improve. Compared to other countries the Portuguese legislation, considered complex and often bureaucratic, could be improved in different issues. The suspension of the IPP framework undermines the future development of PV.

The following table summarises the main features of the solar market in Portugal:

Table 9 - PESTEL analysis of Portuguese solar market

Solar Energy in Portugal		
Political - Strong EU policy influence; - Strong national Government commitment; - Appropriate policy mix, but lacking ambitious objectives; - Political stability at the moment, but with elections in 2009.	**Economic** - Still low importance in the overall energy mix and in the Economy in general; - Important FDI[19] sector, with 3 big projects in Alentejo; - World Global crisis.	**Social** - Low GDP per capita; - High differences in income distribution; - High awareness, but with no correspondent equipments implementation ; - Increasing advertising and social events.
Technological - Low Government and private research spending, taking in consideration the market dynamics; - Few successful R&D projects.	**Environmental** - Plenty of natural resources; - Solar as an important driver for the EU and national energy efficiency and climate change mitigation programmes success.	**Legal** - Comprehensive legal framework; - Feed-in system; - Several tax incentives; - Licensing and complexity problems; - IPP currently suspended

Source: Developed by the Author

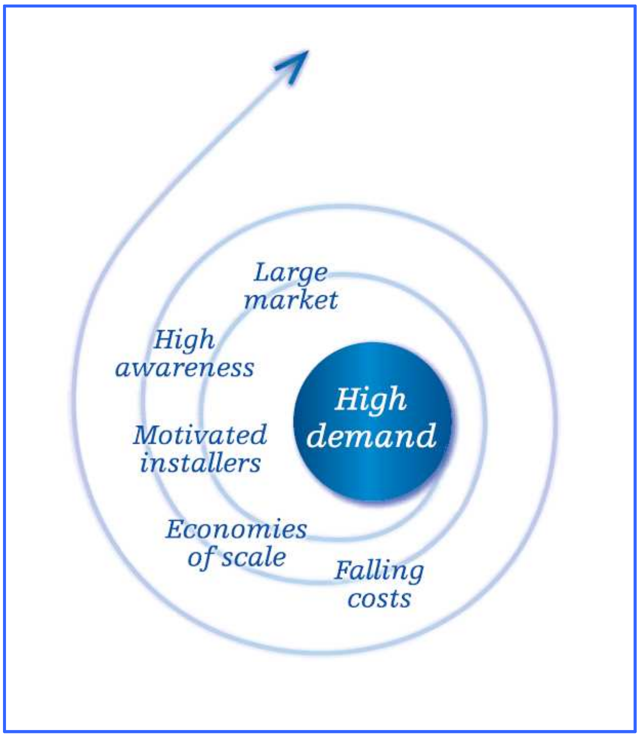
After analysing all these data, there is no doubt that, overall, the overview is favourable to solar energy development in Portugal, however there is still much to do to make it one of the most important sectors of the Portuguese economy.

In recent years, the adopted policies have kicked off a growth that is expected to be more pronounced in the future, essentially because they have created the suitable conditions for a strong demand for this type of technology. According to ESTIF, that is precisely the first step to the creation of a virtuous circle where the growth will become self-sustained. The strong demand will lead to the creation of a bigger market, where production costs will necessarily be lower as a result of the economies of scale achieved. These conditions will encourage installers and producers as a result of both the increasing demand and the raising awareness of

[19] FDI - Foreign Direct Investment

solar energy. Conditions will become even more attractive, for consumers and producers, allowing increased competition and competitiveness in this industry leading to an ever growing market.

Figure 19 - Self-perpetuating cycle of imbalance (Country with Growing Market)



Source: ESTIF (2007)

So, what is the role of RES and solar energy in Portugal? RES will not be alone the resolution to all implicit issues in climate change or in the security of energy supply. But they will be for sure an important part of the problem's solution. The problem will have to be solved through the adoption of energy efficiency measures in transports, industry, families' options, etc., along with energy mix diversification in each country according to their internal resources and global goals. Solar energy will be part of this global solution and it will have its role. In Portugal, from a logic and rational point of view, solar energy should play a major role, given its high potential. In order to explore its potential more efficiently there will have to be more technological investment in this sector. To have availability for a greater investment in technology, companies must increase sales and revenues, reducing unit costs gradually, and the Government will have to create the suitable conditions for that. The Germany case has shown that this is possible in a country with fewer natural conditions for this industry development. Today, RES and solar energy in Germany represent an important part of

German industry, creating strong local economies and industrial clusters that consistently foster their development.

RES and solar energy are already part of the present and they will play a key role worldwide in the future. These markets have all it takes for a strong development: demand, growth perspectives, available resources, interested investors, attractiveness, innovation, lots of advantages and few disadvantages, possibility of decentralised production and even more they contribute to key goals for our planet's sustainability. Some experts argue that the solution to change the energetic paradigm will come from more radical solutions such as "clean coal" or nuclear fusion power plants, which may well be true. But when will we have access to such technology? And for what price? We can't afford to lose more time. We must act and act now. According to a recent study called "The impact of renewable energy policy on economic growth and employment in the European Union" carried out for the Directorate-General for Energy and Transport of the European Commission, Portugal is in the top ten of the countries that would most benefit from a strengthening of RES policy, either in employment or GDP (Duarte L., 2009). These conclusions highlight even more the urgency of the development of RES in Portugal. The RES exist and should be used, and among RES, solar energy has huge potential.

4.2. Strategic guidelines

4.2.1. Political/Environmental

In a recent promotion action of RES in Portugal, the Portuguese Government invited 90 students from 16 different countries to visit some of the most emblematic projects in Portugal. Following this event a book entitled "Uma nova era na Energia - Energias Renováveis em Portugal[20]" (Conceição, J., *et al*, 2009) was published, which presents the opinion of several experts and of some of the students invited, with regards to RES in general and the Portuguese case in particular. In this publication, the Minister of Economy and Innovation writes that one major goal of the government is to make Portugal a leader in new energy/environment industries. In order to achieve this goal the strategy is to focus on the comparative advantages of the country and in the appropriate mix of current policies and

[20] A new era in energy - Renewable energies in Portugal

technologies, strongly based on the development of wind and hydro energy. According to the same source, the aim is to reach 2020 with a technologies' portfolio of installed electric capacity where solar energy, biomass and waves represent only 8% of the total.

While the general idea of making Portugal a leader in a specific area such as energy/environment seems to be theoretically appropriate for solar energy development in Portugal, the goal for 2020 of only 8% of installed electric capacity for a technologies set, among which solar energy is included, seems to be clearly a limited target. Indeed, with the definition of such goals, it seems that the executive does not aspire more than just create flag projects in solar which, although important to boost the sector, are only part of a coherent strategy for solar energy promotion and will not be decisive for the suitable development of industry according to the existing resources in the country. For a real exploitation of existing resources an ambitious policy will be needed, with ambitious and bold goals, to eventually be able to help revolutionise these markets. After the setting of ambitious targets, the government has to develop a greater effort in the implementation of measures, because often good plans transform themselves in bad measures mainly because there is a flaw in implementation.

For this purpose, and as it is already implemented in Germany, it will be necessary a very efficient, flexible and "on real time" organisation of the monitoring systems for the success of measures and goals set, otherwise those measures can be a barrier to the industry development. If the defined target is quickly achieved, then what in the beginning can be seen as an incentive will soon become an obstacle to a more dynamic development of the industry, because it can fail to have the previous support and incentives, diverting the investors' interest. For example, in Decree-Law 363/2007, the definition of limits from which the subsidised tariffs stop being paid can effectively act as a brake on micro-production development. The current suspension of the traditional IPP is another example of how the definition of conservative limits can act as a brake for PV development. In a sector where resources are so abundant, which has investors interest and unquestionable benefits, there should not be any limit to the industry development.

Another current problem of solar energy sectors in Portugal, and in all countries that have a significant solar market in general, is that their growth and development is dependent on the State intervention. Besides feed-in systems, which make the purchase and installation of PV systems real investment projects, there is a series of other measures and incentives to promote thermal and PV solar energy. This Government's intervention is absolutely essential for the initial development of these industries. However, in the medium and long term a strategy for the progressive operation of free markets must be defined, under the threat of these becoming completely artificial and even more volatile than current markets of fossil fuels. For example, as observed in German solar thermal market, in 2002, there was an economic slump as a result of less availability of subsidy funding. These situations occur when markets are very dependent on State intervention and should be eliminated for a real competitiveness. The State intervention will have as last goal to make them autonomous, flexible and consistent markets, so they can, in a near future and when the production costs decrease to acceptable levels, work normally. *I.e.*, a strategic framework will have to be defined today, when the support policies for these markets are set, to allow the elimination of those supports, in a progressive way and without significant impacts.

For this to happen, the way people assess solar energy must change. Ultimately, the purchase of solar equipments should be viewed not as an investment project, but like the installation of essential equipment to each house, as occurs with other materials and normal equipment in a house, such as walls, windows, doors, etc. For example, it is not usual, when building a new house, to perform an economic study to consider the installation of single or double glazing windows. Theoretically, any person would prefer double glazing windows that will be much more comfortable and efficient at all levels. But when taking this decision, no one prepares an economic study to check if the price difference between these two types of windows is paid for itself through the inherent benefits of double glazing. People make these decisions in a perfectly natural and automatic way, because they have already internalised that these windows are better than the others. In solar energy it should be the same, *i.e.*, people should gradually let go this purely economical vision because, in fact, solar energy must be essential to each house.

Current Portuguese legislation already foresees the installation of solar energy in new buildings, but there is still a lot to do in this area. As it is already being developed in other countries, one of the measures that can help the most not only to develop and stimulate solar energy markets, but also to generalise the use of such equipments, contributing to the necessary change of minds, would be the mass installation of solar energies in properties under State responsibility. The State is currently responsible for a series of properties like schools, universities, public buildings, hospitals, sport complexes, land properties, etc., where the development of mass actions for solar energies introduction would make all sense for several reasons such as energy efficiency, increase of energy production by RES, potential savings and indirect support to the development of these sectors. The State, besides being a major energy consumer, is responsible for a number of facilities where there are large available areas for solar panels installation and where, in general, there are energy inefficiencies.

But companies can also develop similar programmes. There are cases of business groups that are owners of large facilities, like warehouses, shopping centres, office buildings, etc., which, besides having plenty of free space on the roofs, are also big energy consumers, so inner energy production would be a significant measure to reduce costs. This is a far more common measure in U.S. companies like Wal-Mart and Google, but in Portugal it is starting to be developed by business groups like Sonae.

Finally, and taking into account the suggestion of the highly regarded consulting company McKinsey it must be mentioned that the State should mainly adopt policies that reward the energy production rather than installed capacity, since "*subsidizing capacity rewards power installations regardless of their cost-efficiency, while subsidizing production will effectively create incentives to constantly reduce costs, production efficiency and technology development*" (Lorenz, P., *et al*, 2008). In Portugal this measure will make more sense for facilities with large installed capacity, since for smaller ones the production is indeed already being rewarded through the feed-in system.

In the field of policies for sustainable development, climate change and environmental protection, the EU has been a benchmark to the world. EU is being very dynamic promoting a series of concrete measures that enabled its countries to reach their current development stage. There are still many divergences but there are common goals and the paths to follow, although differentiated among nations, will all reach the same destination. As confirmed throughout this document, in the Portuguese case, the EU has had a strong influence not only regarding RE and solar energy in particular, but also with regard to energy efficiency, energy security and environmental protection. The common energy policy represents a major challenge for the EU, and its main drivers are not only the energy security issue and environment protection, but also ensure that, while maintaining or increasing the competitiveness of the European companies (see annex 8).

Assuring that Portugal will positively be influenced by EU measures, the current course of policies internally adopted should therefore be kept, in order to promote the sector development. It is still necessary that, despite any Government change occurring during 2009, the new executive carries out its mandate with determination and ambition regarding RE.

4.2.2. Economic

The majority of the world economies are currently facing a difficult time. What has begun as a financial crisis in USA, has become one of the biggest financial and economic crisis worldwide, affecting almost all industries, including RES. The financing difficulty has increased, due to the reduction of financing availability and to the increase of financing costs. Moreover the capital cost has also increased, *i.e.*, the minimum rate that investors are ready to accept to invest in solar energy projects has increased and this turns unfeasible some projects that in other circumstances would be feasible. However, according to Ernst & Young (2009), in several European countries, although FDI has stagnated in 2008, the machinery and equipment field has seen a 19% increase in FDI initiatives due to a large number of projects for wind turbines, solar components and fuel cells' supply. The existence, for longer than the financial and economic crisis, of an energy/environment crisis, which requires an urgent shift in the energy consumption and production habits worldwide, can be an explanation for this increase.

These data show that even with an unfavourable situation, there is room for growth in solar industry, reason why agents involved in these markets should carry on their development policies. In the development of RE, Portugal could have the comparative economic advantage that it is searching for a long time. Being a small economy compared to others, especially in this technological age in which qualified human resources are absolutely essential, it will make sense to concentrate resources and directing them to a limited number of industries, in order to create suitable conditions to develop this comparative advantage. If this action is focused in a sector like RES, with a guaranteed future and where Portugal has the necessary natural resources, the probability of success will be huge.

One issue that also raises different opinions regarding solar energy exploitation is related with promotion of a centralised or decentralised production. Some experts believe that the large solar power plants involve State supports, which if were directed to small producers would produce more positive effects, not only because they would help to change minds and raise awareness among populations, but also because there are great losses and waste in large power plants, mainly in distribution grids. Those losses would be much lower if production was decentralised. These power plants need a large area, while in micro-production the building roofs could be used, avoiding the space waste and the environment change in the place where these plants would be installed.

However others defend the centralised energy production, mainly with the thermoelectric solar plants because they think that these solar power plants can bring many advantages. One of the advantages pointed out for solar thermal plants is that the technology for energy production used in these plants is similar to the current technology used in fossil fuel power plants, so there are already many years of accumulated experience. On the other hand, as the plant technology is similar to other plants, they also argues that those plants, if necessary, could be adapted to work with another type of fuel. Moreover, they believe that the heat generated by those plants is easily accumulated for reuse.

Both have advantages and disadvantages, but taking into account the economic, industrial, social and climate features of Portugal, both make sense in the near future, since the solar energy potential in Portugal is huge and should be fully exploited in many different ways. Mainly due to energy efficiency and the society's involvement, the focus should be on decentralised production, but a balance between architectural conservation and the massive installation of solar panels should be found in order to make these processes simpler, flexible and clearer. Micro-production has a huge growth potential and has great relevance to small and medium-sized companies operating in solar energy sector. In addition, micro-production avoids waste (energy, space and resources), replaces polluting energies for clean energies and is more suitable for a source of energy that is not always available.

The centralised production could also have a vital role, mainly at macro goals level. Even if the case of PV power plant in Moura (Amareleja) is largely considered as only one flag project with no substantial structural benefits, the centralised energy production is an important contribution to the mass production of energy from renewable sources, which can be important for the development of local economies. Bearing in mind that the best weather conditions and land availability for the installation of these plants are located in the interior centre and southern of Portugal, and at a time when these areas are more and more deserted, both socially and environmentally, the implementation of such projects can help develop local economies, promoting employment and the creation of technological and industrial clusters, boosting the development and prosperity of these areas. Portugal needs to attract more investments like these. However, it has to be ensured that the implementation of these plants is more than another flag project and has to become a real benefit to the national industrial value chain, in terms of R&D and equipment production. In addition, those projects are in fact flag projects that help promote solar energy internally and increase its awareness, and help promote the image of Portugal as a sustainable country.

A good example of a country that has largely made use of the inherent advantages of RES and specifically of its solar energy potential is Spain. According to Público (2009) in Andaluzia, a neighbouring zone, whose weather conditions are similar to the south of Portugal, in July 2009, the largest solar thermal power plant in Europe with 50 MW power was inaugurated. In addition to this power plant, 9 other solar thermal power plants are still projected to Andaluzia. As soon as all these projects are running, this Spanish area will have 648 MW of solar thermal power plants, which will prevent the emission of 435,660 tons of CO_2, equivalent to removing 174,264 vehicles from circulation.

Another issue that should be developed is the promotion of synergies with CPLP[21] countries. This group of countries, besides having a great cultural proximity to Portugal, have natural resources, sun, large available areas, which among others are essential for RES development and solar energy in particular. These countries represent huge markets with fantastic business opportunities at all levels, such as equipment production, installation, research or solar energy exploitation. The potential is huge and recent news reveal, for example, that one group of 12 companies, among which are 10 German companies, is studying the feasibility of a giant project in Sahara desert to produce solar thermal energy for Europe and Northern Africa. If achieved, this giant project would involve investments of around 400 thousand million Euro. These units could produce 15% of annual energy consumed in Europe (Krippahl, C., 2009). Although Portugal can not aspire to projects with this magnitude, this news confirms the solar

[21] CPLP - Community of Portuguese Language Countries - Portugal, Brazil, Angola, Mozambique, Cape Verde, Guinea-Bissau, São Tomé and Principe and East Timor

power plants potential, its great potential impact on energy revolution, the interest of a country like Germany in this type of development and the opportunities that the cooperation with other countries can generate (see annex 9).

4.2.3. Social

To fight climate change and increase security of supply, there will have to be a strong contribution and accountability of all economy sectors. However, if in sectors such as transport or industry it may be easy to find responsible among public or private companies, associations, etc., in the residential sector the accountability is much more difficult. We all belong to this sector and the probability of "free-riding[22]" is very high. For real changes in citizens' attitudes, a change in behaviours and minds has to occur. Besides raising awareness, training and education, always essential for these changes to happen, solar energy, both PV and solar thermal, could have a crucial role in achieving this goal.

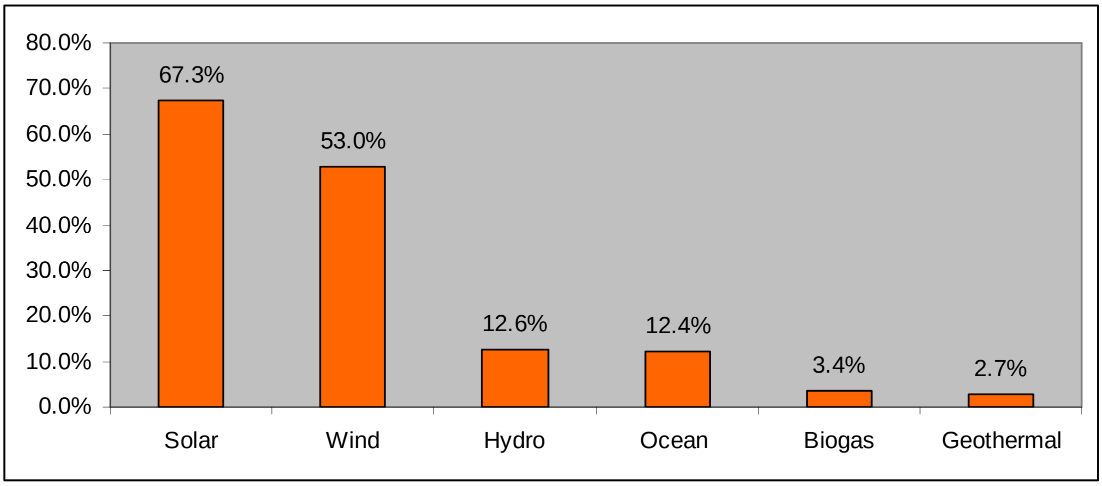
Solar thermal is already a mature technology, with lower costs and therefore more accessible to a greater percentage of the Portuguese population. Furthermore, campaigns such as the ongoing until the end of 2009, allow even more cost reduction in equipment purchasing. In addition, for new housing, in certain circumstances, the installation of solar thermal collectors is required by the current law. Therefore, it is expected that the penetration rate will increase to significantly higher values than it has been so far. Thus, this technology shows a very high growth potential, helping to change behaviours and minds concerning energy and climate change approach. Regarding PV, and to micro-production in particular, some experts also argue that it may have a key role in changing minds and behaviours for two main reasons. First, because the new law allows any citizen to be an energy producer, and sell that energy to the distribution grid at an attractive price, making him an entrepreneur with a business that can be both profitable and sustainable for the planet. On the other hand, knowing that in Portugal there is a limit on selling energy to the grid by a subsidised tariff, the micro-producer will tend to optimise his own energy consumption (through energy efficiency measures) to reduce his costs and increase his business profitability as a whole.

[22] The Free-riding problem in this context refers to those people who don't change their actions towards problems such as pollution, that is harmful to the environment and to air quality (public good), waiting that others can do it

The government can have an important role helping change behaviours and increasing the awareness of solar energy, firstly by informing and educating the citizens. Greece has become the second largest solar thermal market in EU using, among other measures, this approach of informing and educating citizens about the benefits of solar thermal.

So, the impact that solar energy can have on the energy revolution in Portugal may be underestimated, if only based on efficiency and financial analyses of the different available technologies. Among all RE, solar energy is the closest to the citizens and the one that can more quickly help change mind sets. This conclusion, although empirical, can be supported by studies like the one presented by Cetelem (2008), a credit company, about the Portuguese market for RE. This study, based on telephone interviews with individuals from 25 to 64 years old, has concluded, among other issues, that solar energy is the RE with greater spontaneous awareness, followed by wind and hydro energy. The spontaneous awareness of solar energy is 67.3% and its overall awareness has reached values of 97.5%, which clearly shows its proximity to the Portuguese citizens.

Figure 20 - Spontaneous awareness of different RES



Source: Cetelem (2008)

However, when analysing the percentage of the respondents universe that actually have solar energy equipment, only 4.4% of respondents state they have PV panels, and only 1.1% have solar thermal collectors, so there is a clear gap between solar energy awareness and its implementation, which is a reason why there should be an effort at a commercial level to make the penetration of these equipments closer to their reputation.

Among the reasons that can explain this gap is another conclusion of this study. The two main motivations for the choice of a shop/brand of RE equipment are the guarantee of technical assistance and the quality of available equipment. These results suggest that, like in the past, there is great concern about the quality of RE equipment, and solar equipment in particular, which is why the certification is absolutely essential to increase consumers' confidence. As already seen, this was pointed out as one of the reasons for the weak development of the Portuguese solar industry compared to other countries.

Also, at a marketing level an effort should be made especially by companies. Interestingly, contrary to what happens to other markets, in Portugal, the state and industrial associations are the major responsible ones for the promotion of solar energy. Indeed, rarely is seen an advertisement from private companies in the media, so the companies themselves should also be responsible for the poor promotion of solar energy. In a country where utilities dominate the energy market and have privileged relationships with the residential, commercial and industrial customers, small and medium-sized companies should be commercially aggressive in order to compete with utilities. For the small and medium-sized companies, the hypothesis of some partnerships with utilities should be considered in order to access to their commercial networks. Utilities should consider partnerships as a way of not losing this "moving train".

If we consider that every citizen has a home with a specific energy consumption, uses public transports or his own transport, walks or cycles, works in a small or large company, takes professional decisions that have impact in energy efficiency and climate change, is a consumer of different products, and so on, it can be easily concluded that the common citizen is the basis for all decisions. So, the positive changes we need depend on us and we are those who decide about the future in terms of energy and environment. Solar energy, having great proximity to the common citizen, could have a major contagious effect on other areas. This potential contagious effect of solar energy should be explored to the most, and therefore Government must be very ambitious when defining its goals.

4.2.4. Technological

Regarding R&D, there has been a very positive evolution in recent years in Portugal. According to the Ministry of Science, Technology and Higher Education (2008), from 2005 to 2007, R&D expenses have increased more than 50% in real terms, setting up a value of

1,920 million euros in 2007. For the first time in the Portuguese history, in 2007, R&D expenses in the companies sector exceeded other institutions expenses (Government, Higher Education and Private Non-profit Institutions). The companies sector represents about 1,010 million euros in R&D expenses, immediately followed by the Higher Education sector with about 586 million euros. The R&D expense in the energy sector was the one that most increased from 2005 to 2007, a rise of about 80 times the previous value, but still represents a low percentage of the total, about 4%, well below other sectors like financial and insurance services, IT and communication services. Concerning solar energy, according to the IEA-PVPS annual report, "*fundamental research activities are carried out in a dozen public and university R&D units and address mainly thin film technologies, crystalline silicon ribbon and organic cells. Applied research, demonstration and dissemination are performed in several institutions such as public research institutes, energy agencies, utilities and private research institutes*" (Paes, P.,S., 2009). Even if there are some R&D activities, only a few R&D projects resulted in commercial products.

Taking into account the sector's potential in Portugal and the recent global trends in R&D, this is clearly an area where solar industry in Portugal can grow considerably. The Government has made a recognised effort in the development of R&D areas and solar industry should take advantage of this current trend and learn from the systems of other successful countries, like Germany, to deepen its activities of R&D and promotion of innovation and technological development. One of the most interesting measures to implement is to promote cooperation between sectors, especially between companies and universities, as it often happens in Germany. In a small country like Portugal, where the two sectors that spend more money for R&D are precisely the companies and universities, it makes all sense that they share knowledge and information, which not only will bring benefits to both, but will also increase the probability of success. The example mentioned in chapter 2.3, about solar tiles, is precisely a case of success resulting from partnerships between companies and universities, among others. It should also be more explored the relationship between Portuguese and foreign institutions and companies, using the fact that Portugal is, in Europe, the ideal laboratory for the study of technological developments in solar energy.

Concerning the sectors to be developed through R&D, the PV solar energy is the one that shows better development potential as it is still in its infancy, particularly thin-film technologies, which still show relatively low efficiency levels, with a still uncertain durability, but with great possibilities for innovation. This is indeed the IBM prediction, presented in its study "Next Five in Five", where the 5 innovations that will change our lives over the next 5 years are identified (Rodrigues, C., 2009), and where solar energy and thin-film technology is identified as a possible revolution in the way energy is produced. The storage solutions for produced energy, are also those that will become increasingly important for solar.

4.2.5. Legal

Regarding legislation, both for energy efficiency and RES, Portugal has already implemented a series of mechanisms at the level of the world best practices, as it has been widely discussed in the previous chapters, however there are still issues that can be improved.

A unique legal framework for the traditional IPP and for micro-production, like the one that exists in Germany, should be considered in the future amendments to the feed-in system. Also, a simplification of the tariffs definition would be an advantage, especially for the traditional IPP, where the calculation of the tariffs is complex. The tariffs should be clear and previously defined, making it easy to understand and to interpret all possible solutions. It should exist much more complementarity between these 2 frameworks. The introduction of longer-term stability, increasing the duration of subsidised tariffs, should also be considered for IPP. The defined limits for PV under the IPP framework should be renegotiated to allow the full development of this industry. As seen previously, the strong impact that solar energy has in society could eventually justify the limit increase for PV in detriment of other energy sources.

In the micro-production the possibility of introducing longer-term stability should be considered, to increase investors' confidence. Taking into consideration the limits defined, there is only guarantee of fixed tariff for the first 5 years (excluding the installation year) and 10 years of variable subsidised tariff. Among a variety of hypotheses that could help boost the market, the extension of the fixed tariff should be considered, for example, for the first 15 years regardless the defined limits or/and subsidise the tariffs for more 5 years, making it a total of 20 years of subsidised tariff, as it is in Germany. The elimination of annual limits should be considered, both for production and registration, because they can limit the total capacity of electricity production through micro-production, besides implying also limitations and difficulties in units' registration system. A degressions system should be considered, which works based on a technology learning concept, instead of limiting the capacity to reduce subsidised tariffs. The SRM should be redefined to work in a more reliable and continuous way and to provide the same registration opportunities regardless of the prospects' size and resources.

In the solar thermal sector the actions that have been developed to encourage the market are essentially isolate and are under a number of other plans for energy efficiency and sustainability. The fact that they are essentially isolate measures and without a sustained long term plan, could eventually make its understanding less clear by consumers, following the constant change of measures developed, besides making them more short-term measures, introducing also uncertainty in the sector. For example, although the programme developed by Government for implementation in 2009 is an excellent program to promote solar energy in terms of incentives and communication (not necessarily understanding), as it is a short-term one (finishes at the end of 2009) and it is only directed to some situations, it will always have a limited impact. The truth is that in this industry, despite being recognised by consumers, there is still very little deep knowledge of it, so the purchasing decisions will take longer than for equivalent equipment but with greater penetration. In addition, also the installers claim that programme raised enormous doubts and issues about how it works. Considering the current financial and economic crisis and the many questions and doubts both from the installers and consumers, these types of programmes could eventually have the opposite outcome because they bring confusion and distortion to the markets. The programmes should be more comprehensive for installers and consumers, designed to all sectors, last longer periods (as in Germany), and involve the maximum players as possible, to have the maximum impact.

Although there is already a good framework for solar thermal energy in new buildings, it would also be necessary to create a general framework not only for new buildings but also for all existing buildings. The basic idea would be the promotion of solar thermal energy in a sustained and consistent way in all sectors from the residential, industrial, to the State itself, with a flexible view of medium/long-term.

Conclusion

There is huge potential for solar energy in Portugal. This sector is still in its infancy, however if Portugal could learn from the experience of countries like Germany, it would probably have more success in the road ahead. The idea is to avoid mistakes and to adapt and optimise successful measures adopted by reference countries, to rapidly develop this industry and recover the time lost in the past.

In Portugal, the renewable energies boosting took place mainly in the 21st century and, for the last 3 years, the country has experienced a period of strong development in solar energy. This strong development is due to the influence of European Union energy policies, the national plans for energy efficiency, specific legislation to encourage the renewable energies use and specific programmes supporting solar energy, among other important reasons.

In Germany, the growth of renewable energies has been occurring since the 90s, giving it a wide experience in policies for renewable energies' development and showing a much greater advance in the solar energy sector comparing it to Portugal, in the fields of research, production and implementation.

The obvious conclusion is that the development of the solar sector is much more than just the wide availability of solar radiation. The development policies adopted by each country are essential. Different legal frameworks, government determination and even cultural and educational differences between countries are just some of aspects that can determine the success of the solar energy in each country.

Overall, the overview is favourable to solar energy development in Portugal, however there is still much to do to make it one of the most important sectors of the Portuguese economy. For a real exploitation of existing resources an ambitious policy will be needed, with ambitious and bold goals. After the setting of ambitious targets, the government has to develop a greater effort in the implementation of measures. The government can have an important role helping change behaviours and increasing the awareness of solar energy, firstly by informing and educating the citizens

Measures such as the mass installation of solar energy equipments in properties under state responsibility, the promotion of both centralised and decentralised production, the promotion of synergies with CPLP countries and the promotion of cooperation between companies and universities for R&D, are just some of the measures that can make the difference. Also, at a marketing level an effort should be made especially by companies.

Regarding the Portuguese legislation, a unique legal framework for the traditional IPP and for micro-production, a simplification of the tariffs definition, the introduction of longer-term stability, the elimination of annual limits both for production and registration, or, regarding solar thermal, the development of a general framework not only for new buildings but also for all existing buildings could be positive changes to implement.

In this industry there are several threats to consider, such as the increasing competition between different countries, regardless of being more technological based or more low costs based, or even the increasing competition between different technologies. However, Portugal should focus on its opportunities to overcome the competition and transform the solar energy in a prosperous sector.

The wide natural resources availability compared with other competitors, the inherent flexibility of a small country, the influence of EU's policies in RES, the strong Government commitment, the appropriate policy mix and legal framework, and the close relations of Portugal with CPLP countries, are only some of the reasons that bring optimism for the future of solar energy in Portugal.

However, governments, politicians, companies, consumers and the society in general should not lose any more time. Portugal should define ambitious targets and use innovation to make the difference and become itself a reference in the solar industry.

Bibliography

- Monographs/Books, contributions to collective works, periodicals, press and references taken from the internet:

ADENE/INETI (2001), *Fórum "Energias Renováveis em Portugal" – Relatório Síntese.*

ADENE (2009), Água quente solar, Caracterização do solar térmico em Portugal 2008, relatório síntese, http://www.aguaquentesolar.com/_fich/18/Caract_ST_Pt_2008.pdf

Aguiar, R. and F.D. Santos (2007), Prospective Model for Greenhouse Gas Emissions in Portugal. Version 2.2 Final Report, Volume I: Reference Scenarios (*in Portuguese*). *Project MISP - Climate Change: Mitigation Strategies in Portugal*, Calouste Gulbenkian Foundation and Instituto D. Luiz, Lisbon, 130-142.

Bundesverband Solarwirtschaft (2008), German Photovoltaic industry overview, as of 2008, http://www.en.solarwirtschaft.de/home/photovoltaic-market/german-market.html

Bundesverband Solarwirtschaft (2008), Overview of the German solar thermal industry (from 2008), http://www.en.solarwirtschaft.de/home/solar-thermal-market/german-market.html

Cetelem (2008), *As Energias Renováveis – O mercado nacional*, "O Observador Cetelem".

Conceição, J., *et al* (2009), *Uma nova era na Energia – Energias Renováveis em Portugal*, Edições Económico

Directorate-General for Energy and Transport (2007), *Renewables make the difference*, European Commission.

Directorate-General for Energy and Geology, Portugal (2009), *Renováveis – estatísticas rápidas – Maio 2009*, No. 51.

Duarte, L., (2009), Portugal no top ten dos países que mais beneficiam com aposta nas renováveis, *Água e Ambiente*, 1st of July

Eco Solar Equipment (2009), Why solar?, http://www.ecosolarequipment.co.uk/why_solar.asp

Eloy, A. (2009), *Energias Sem-Fim, Contrariando as alterações climáticas*, Edições Colibri

EPIA (2008), *Photovoltaic energy - electricity from the sun*, http://www.epia.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/EPIA_docs/publications/epia/Epia_Techno_leaflet_FINAL_WEB.pdf&t=1247909638&hash=eb3b052d5a63e6cb81e391e2832a9c4e

EPIA and Greenpeace (2008), *Solar Generation V - 2008, Solar electricity for over one billion people and two million jobs by 2020*.

Ernest & Young (2009), *Reinventing European growth - Ernst & Young's 2009 European attractiveness survey*

ESTIF, (2007), *Solar Thermal Action Plan for Europe - Heating & Cooling from the Sun*.

ESTIF (2009), Solar Thermal Energy, Technology, website information,
http://www.estif.org/st_energy/technology/introduction/
http://www.estif.org/st_energy/technology/solar_domestic_hot_water_heating_sdhw/
http://www.estif.org/st_energy/technology/combisystems/

European Commission (2007), *Concentrating Solar Power - From research to implementation*, Directorate-General for Energy and Transport and Directorate-General for Research ,7-9.

European Renewable Energy Council (2008), *Renewable Energy Policy review - Germany*.

European Renewable Energy Council (2008), *Renewable Energy Policy review - Portugal*.

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008), *Renewable Energy Sources in figures - National and International Development*.

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008), *Heat from renewable energies - what will the new Act achieve?*, page 21

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Germany (2009), *Development of Renewable Energies in Germany in 2008*, as at April 2009, Data of the Federal Environment Ministry on the development of renewable energies in Germany in 2008 (provisional figures) based on information of the Working Group on Renewable Energy Statistics (AGEE-Stat).

Green Car Congress (2009), Solar Roadways named a finalist for 2009 EE times ACE awards, http://www.greencarcongress.com/2009/02/solar-roadways.html

Held, A., Ragwitz, M., Huber, C., Resch, G., Faber, T. and Vertin, K. (2007), *Feed-in systems in Germany, Spain and Slovenia - A Comparison*, Fraunhofer - ISI, Germany, Energy Economics Group, Austria, Agencija za prestrukturiranje energetike d.o.o., Slovenia, 3-7; 26-35.

International Energy Agency (2007), *Energy Security and Climate Policy – Assessing Interactions*, 24-30.

International Energy Agency - Photovoltaic Power Systems Programme (2008), *Trends in Photovoltaic applications - Survey report of selected IEA countries between 1992 and 2007.*

Krippahl, C. (2009), Doze empresas arrancam com projecto solar no Sahara, *Diário Económico*, 17th of July.

Lorenz, P., Pinner, D. and Seitz, T. (2008), The economics of solar power, *The Mckinsey Quarterly*, number 4, 67-79.

Ministry of Economy, Directorate-General for Energy, Portugal (2001), *Eficiência Energética e Energias Endógenas*.

Ministry of Economy and Innovation (2007), *Renewable energy in Portugal*, 38-45

Ministry of Economy and Innovation (2008), Portugal Eficiência 2015 – Plano Nacional de Acção para a Eficiência Energética, http://www.portugal.gov.pt/pt/Documentos/Governo/MEI/PNAEE.pdf

Ministry of Economy and Innovation (2009), A Energia Solar quando nasce é para todos, http://www.paineissolares.gov.pt/

Ministry of Economy and Innovation (2009), Medida solar térmico 2009, http://www.min-economia.pt/document/MEIMedida2009SolaTermico20090803.pdf

Ministry of Science, Technology and Higher Education, Gabinete de Planeamento, Estratégia, Avaliação e Relações Internacionais, Portugal (2009), *Sumários Estatísticos – IPCTN.07 – Inquérito ao Potencial Científico e Tecnológico Nacional*.

Ministry of Science, Technology and Higher Education (2008), Notícias, Despesa em I&D em Portugal com maior crescimento na Europa, http://www.mctes.pt/?idc=34&idi=1896

Niesing, B. (2009), Using Energy Efficiently, *Fraunhofer Magazine*, 1, 8-14

Paes, P.,S. (2009), *Portugal - PV Technology Status and Prospects*, IEA-PVPS Annual Report 2008.

Piebalgs, A. (2007), in *Renewables make the difference*, European Commission, page 1

Público (2009), Andalucía estrena la mayor planta termosolar europea, *Jornal Público*, 2nd of July, http://files.publico.es/estaticos/pdf/ficheros/pdf/02072009.pdf?r=2107200920

REACT - Case study 3 (2004), Solar-Thermal Energy - Market Incentive Programme, http://www.senternovem.nl/mmfiles/Solar-Thermal%20Energy-Market%20Incentive%20Programme_tcm24-117019.pdf

REACT - Case study 8 (2004), The 100,000 roofs Programme, http://www.senternovem.nl/mmfiles/The%20100.000%20Roofs%20Programme_tcm24-117023.pdf

Renováveis na Hora (2009), Guia para a certificação de uma unidade de microprodução, http://www.renovaveisnahora.pt/c/document_library/get_file?folderId=15654&name=DLFE-3702.pdf

REN21 (2008), *Renewables 2007 Global Status Report* (Paris: REN21 Secretariat and Washington, DC: Worldwatch Institute).

Rodrigues, C. (2009), 5 inovações que mudarão as nossas vidas nos próximos 5 anos, *RM – RevisMarket*, 1st of January.

Rosa, A (2009), Azulejos eléctricos, *Visão*, 19th of february, page 86

Schäfer, O., Zervos, A., Teske, S., Béranek, J. and Tunmore, S. (2008), *Energy Revolution - A Sustainable Global Energy Outlook,* European Renewable Energy Council and Greenpeace.

Solarordinances (2009), Ten good reasons for choosing solar thermal, http://www.solarordinances.eu/SolarOrdinances/Whysolarthermal/tabid/71/Default.aspx

Southface (2009), History of Solar, http://www.southface.org/solar/solar-roadmap/solar_how-to/history-of-solar.htm

U.S. Department of Energy (2005), Solar energy technologies program, http://www1.eere.energy.gov/solar/pv_physics.html

Vasconcelos, S. (2009), Indústria nacional na linha da frente da Inovação, Água e Ambiente, 1st of July

- Portuguese Legislation (*in Portuguese*)

Ministry of Industry and Energy (1988), *Decreto-Lei n. º 189/88*, de 1988-05-27, available in http://dre.pt/pdf1sdip/1988/05/12300/22892296.pdf

Ministry for Environment, Spatial Planning and Regional Development (2001), *Decreto-Lei 339-C/2001*, de 2001-12-29,
available in http://dre.pt/pdf1sdip/2001/12/300A01/00020003.pdf

Ministry of Economy (2002), *Decreto-Lei n.º 68/2002*, de 2002-03-25,
available in http://dre.pt/pdf1sdip/2002/03/071A00/28372839.pdf

Ministry of Economic Activities and Labour (2005), *Decreto-Lei n.º 33-A/2005*, de 2005-02-16, available in http://dre.pt/pdf1sdip/2005/02/033A01/00020009.pdf

Presidency of the Council of Ministers, *Resolução do Conselho de Ministros n. º 169/2005*, de 2005-10-24, available in http://dre.pt/pdf1sdip/2005/10/204B00/61686176.pdf

Ministry for Public Works, Transport and Communications (2006), *Decreto-Lei n. º 80/2006*, de 2006-04-04, available in http://dre.pt/pdf1sdip/2006/04/067A00/24682513.pdf

Ministry of Economy and Innovation (2007), *Decreto-Lei n. º 225/2007*, 2007-05-31, available in http://dre.pt/pdf1sdip/2007/05/10500/36303638.pdf

Ministry of Economy and Innovation (2007), *Decreto-Lei n. º 363/2007*, 2007-11-02, available in http://dre.pt/pdf1sdip/2007/11/21100/0797807984.pdf

- Documents concerning German Legislation (*in English*)

Electricity Feed-in Act 1991, available in http://www.loy-energie.de/gesetze/feed-law.htm

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2000), *Act on granting priority to Renewable Energy Sources*, 2000 Renewable Energy Sources Act, available in http://www.bmu.de/files/pdfs/allgemein/application/pdf/res-act.pdf

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2004), *The main features of the Act on granting priority to renewable energy sources*, 2004 Renewable Energy Sources Act, available in http://www.bmu.de/files/english/renewable_energy/downloads/application/pdf/eeg_gesetz_merkmale_en.pdf

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008), *Payment provisions in the future EEG for the year 2009, as adopted by the German Bundestag Parliamentary Decision from June 6, 2008 EEG*, available in http://www.bmu.de/files/pdfs/allgemein/application/pdf/eeg_verguetungsregelungen_en.pdf

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008), *Act Revising the Legislation on Renewable Energy Sources in the Electricity Sector and Amending Related Provisions*, translation, available in
http://www.bmu.de/files/pdfs/allgemein/application/pdf/eeg_2009_en.pdf

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008), *The Renewable Energies Heat Act in brief*, available in
http://www.bmu.de/files/pdfs/allgemein/application/pdf/ee_waermegesetz_fragen_en.pdf

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008), *Heat from renewable energies - what will the new Act achieve?*

- European Legislation (*in English*)

European Parliament and the Council of the European Union (2001), *Directive 2001/77/EC* of of 27 September 2001,
available in http://eur-lex.europa.eu/pri/en/oj/dat/2001/l_283/l_28320011027en00330040.pdf

- Forums and Conferences

Lisbon Energy Forum, http://www.lisbonenergy.com/

Lisbon Innovation and Renewable Conference,
http://www.cotecportugal.pt/index.php?option=com_content&task=view&id=710&Itemid=72&lang=pt

IV Renewable Energies Conference, http://videos.sapo.pt/C5dt1iZQUunnZ3zVKj5w

Annexes

Annex 1 - Examples of different types of renewable energies

Photovoltaic Panels
(Picture: Author)

Old Windmill in Portugal
(Picture: Francisco Colaço)

Modern Wind Farms
(Picture: Ministry of Economy and Innovation)

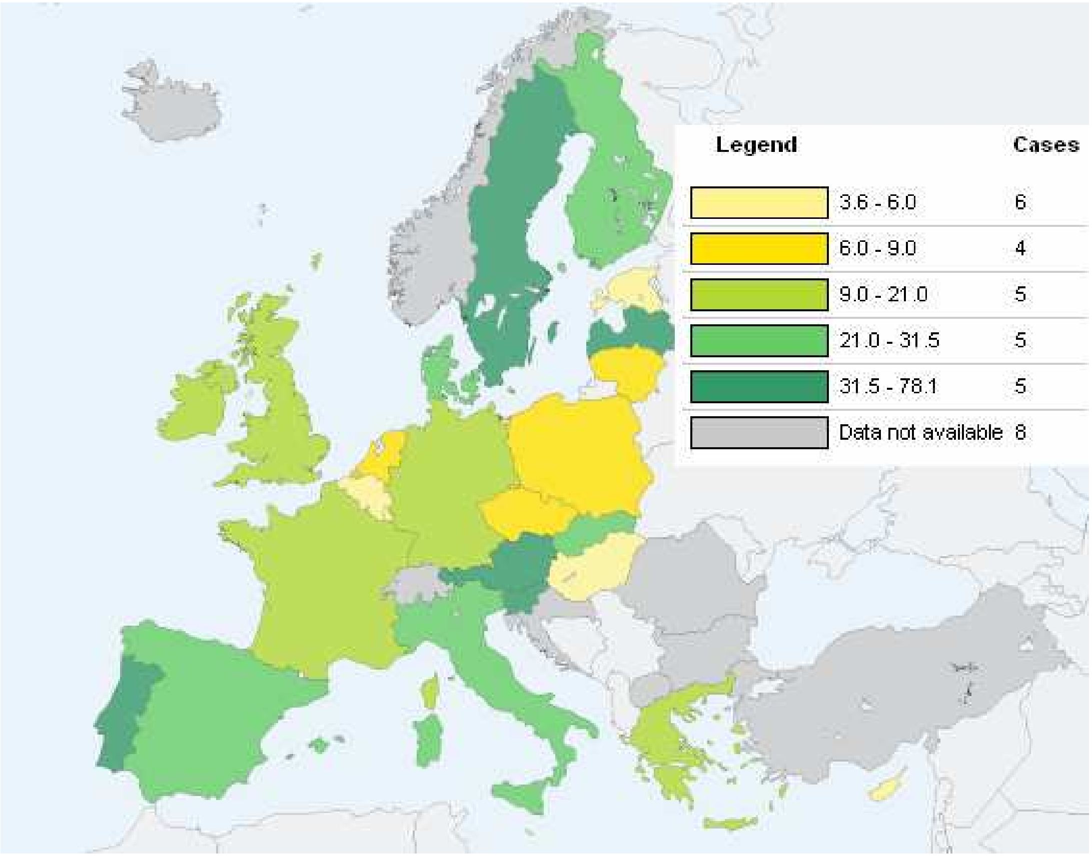
Aguçadoura Wave Farm in Portugal
(Picture: Pelamis wave power)

Industrial Geothermal plant in Azores
(Picture: Arena)

Alqueva Dam
(Picture: Author)

Annex 2 - Electricity generated from renewable energy sources in the European Union

Figure I - Electricity generated from RES in 2010 (% of gross electricity consumption)



Source: Eurostat

Annex 3 - Examples of different solar systems

Solar collectors - Lisbon roof
(Picture: João F. Saraiva)

Building integrated PV
(Picture: Solar Fabrik)

CSP - Solar power tower - PS10
(Picture: Abengoa Solar)

Photovoltaic System
(Picture: Author)

Solar Vehicle
(Picture: North American Solar Challenge)

Annex 4 - Important solar projects in Portugal

Solar XXI Building
(Pictures: INETI)

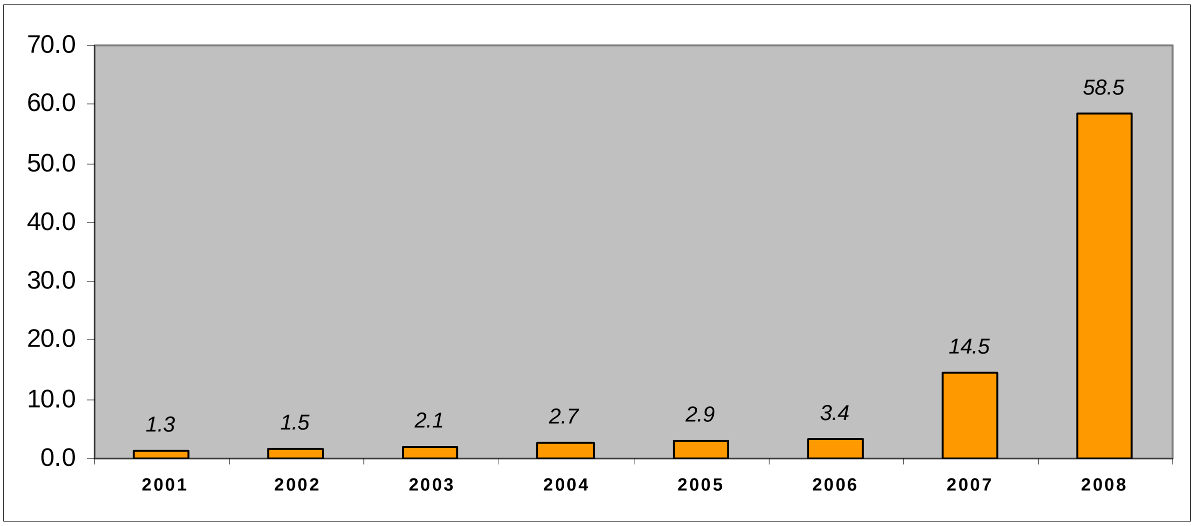
Moura PV power plant - Amareleja
(Picture:Author)

Serpa PV power plant
(Picture:INETI)

Ferreira do Alentejo PV power plant
(Picture:Inês Almeida)

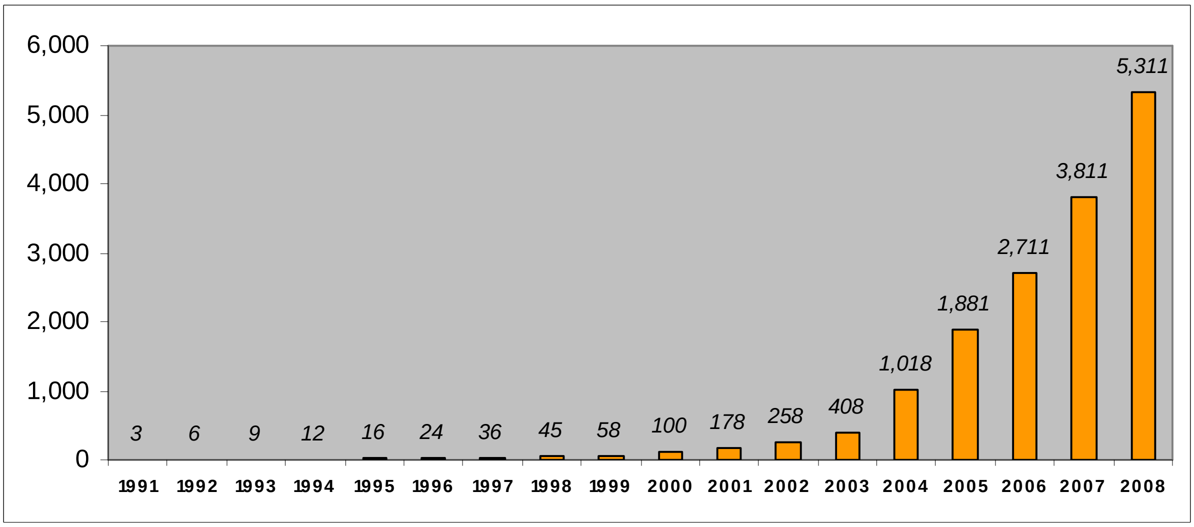
Annex 5 - Photovoltaic cumulative installed capacity in Portugal and Germany

Figure II - PV cumulative installed capacity for electricity generation in Portugal (MWp)



Source: DGEG

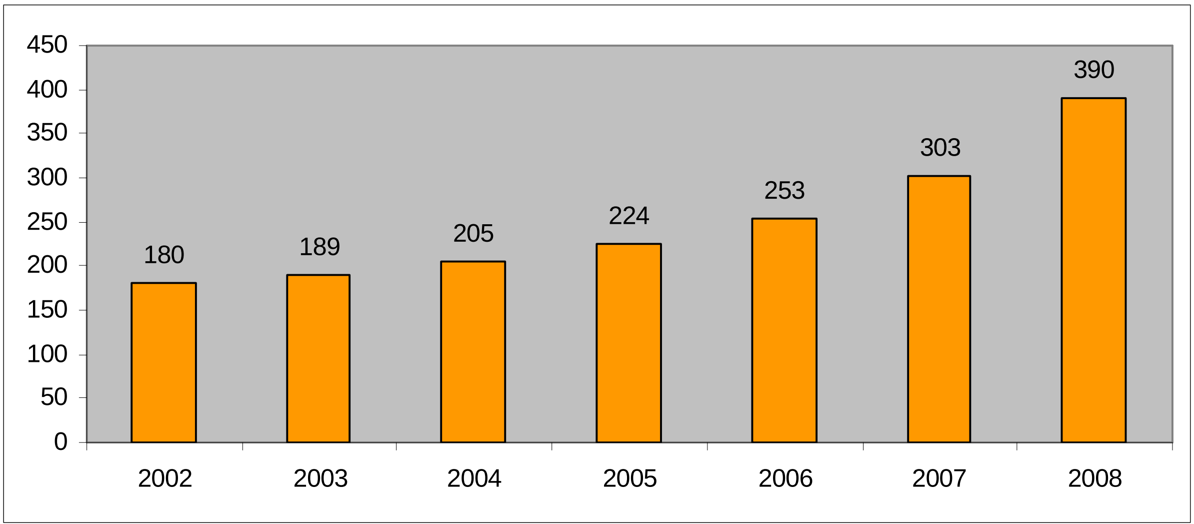
Figure III - PV cumulative installed capacity for electricity generation in Germany (MWp)



Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

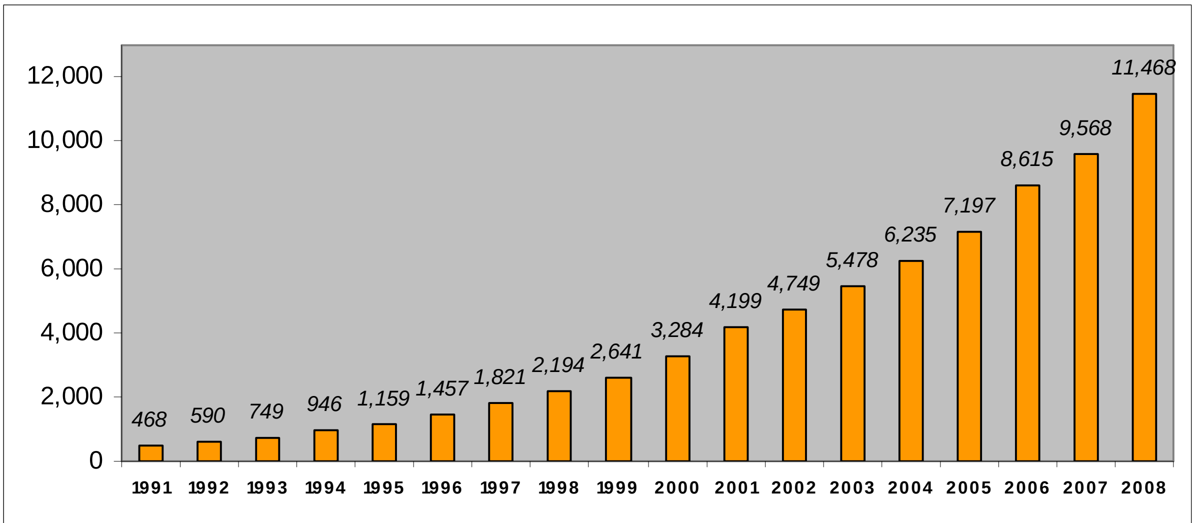
Annex 6 - Solar Thermal cumulative installed area in Portugal and Germany

Figure IV - Solar Thermal cumulative installed area in Portugal (1,000 m^2) - equipments in operation



Source: Adene

Figure V - Solar Thermal cumulative installed area in Germany (1,000 m^2) - includes inoperative equipments

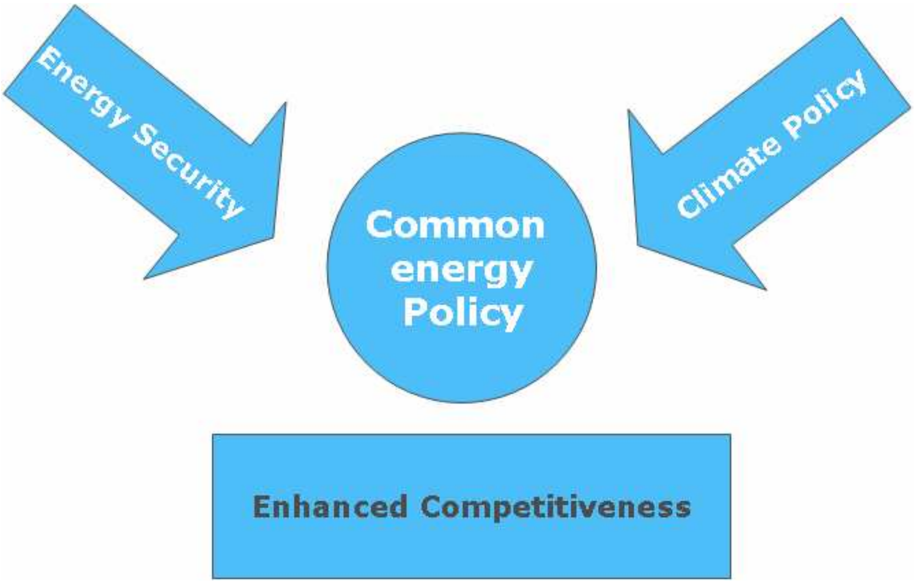


Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Note: Data for 2008 is provisional and is the sum of the 2007 cumulative installed area and the 2008 new installed area. According to the same source, in 2008 only 11,000,000 m^2 were in operation.

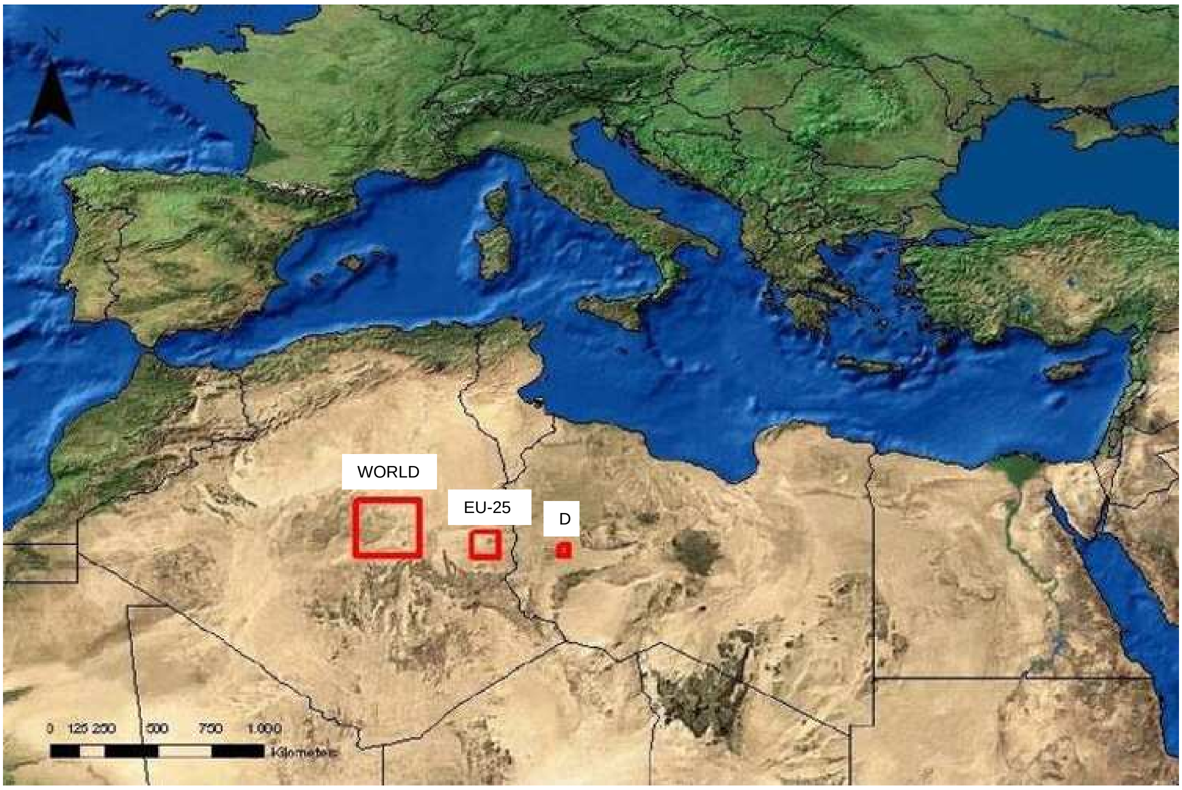
Annex 7 - Examples of the promotion of the Incentive programme for solar thermal in Portugal

Annex 8 - Drivers for a common energy policy in Europe



Source: Developed by the Author

Annex 9 - Sahara's relative solar potential



Source: Spiegel Online (2009), Photo Gallery: Solar Energy from Africa, http://www.spiegel.de/fotostrecke/fotostrecke-43450-9.html

Just to have an idea of the magnitude of such potentials, the left square represents the area required to produce the world's electricity needs, if that particular area was covered with solar thermal power plants. The middle square is the area required to meet the EU 25 countries demand, and the one on the right corresponds to Germany's energy demand.

Annex 10 - Details of the comparison of discounted cash-flows for Portugal and Germany

Estimated Tariffs (€)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Portugal	0.6500	0.6500	0.6500	0.6500	0.6500	0.4100	0.3500	0.2900	0.2300	0.1800	0.1300	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000
Germany	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301	0.4301

Energy produced and fed (kWh)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Portugal	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Germany	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000

Yearly Cash-flow (Tariff X kWh)

	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
Portugal	3,250	3,250	3,250	3,250	3,250	2,050	1,750	1,450	1,150	900	650	500	500	500	500	500	500	500	500	500
Germany	2,151	2,151	2,151	2,151	2,151	2,151	2,151	2,151	2,151	2,151	2,151	2,151	2,151	2,151	2,151	2,151	2,151	2,151	2,151	2,151

Discount rate

Portugal	3%
Germany	3%

Yearly Discounted Cash Flows

	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
Portugal	3,155.34	3,063.44	2,974.21	2,887.58	2,803.48	1,716.84	1,422.91	1,144.64	881.38	669.68	469.57	350.69	340.48	330.56	320.93	311.58	302.51	293.70	285.14	276.84
Germany	2,087.86	2,027.05	1,968.01	1,910.69	1,855.04	1,801.01	1,748.55	1,697.62	1,648.18	1,600.17	1,553.57	1,508.32	1,464.39	1,421.73	1,380.32	1,340.12	1,301.09	1,263.19	1,226.40	1,190.68

Sum of the Discounted Cash Flows

Portugal	**24,002**
Germany	**31,994**