"Project Helios": Can Solar Energy be Exported?

An Assessment Study

An IENE Study Project (M11)

By John Chadjivassiliadis and Costis Stambolis

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Institute of Energy for S.E. Europe (IENE)
3, Alexandrou Soutsou, 106 71 Athens, Greece
tel: 0030 210 3628457, 3640278 fax: 0030 210 3646144
web: www.iene.gr, e-mail:secretariat@iene.gr

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Preface

The utilization of solar energy on a really grand scale for the benefit of mankind has always been in the innermost thoughts of solar pioneers and visionaries. Although solar energy is freely available the means of converting it to useful thermal or electric energy are not. However, thanks to the tremendous technological developments of the last thirty or so years the energy produced through the conversion of solar radiation, especially solar electricity, has reached a level that in certain regions of our planet it can compete price wise with that produced by fossil fuels. Today large scale solar power generation is a reality thanks to the phenomenal advances achieved in photovoltaic technology.

The dramatic decrease in the cost of solar photovoltaic power generation over the last decade has enabled fast market expansion not only in countries with high solar radiation but also in others in less privileged northern climates.(e.g Germany) It can be safely said that in the foreseeable future and following a further sharp fall in the price of photovoltaic (PV) modules and the balancing of the system, and depending on the geographical location of solar installations, PV power generation will be in a position to compete with fossil fuel generation. Grid parity in Europe is fast approaching and looks likely to be achieved in the current decade starting from SE Europe.

Market forces and astounding technological innovations are pushing PV power generation to compete much faster than could, until recently, be conceived with conventional fuel sources. And although solar photovoltaic, like other renewable sources, notably wind, suffer from their intermittent nature, the sere size of plants under development at a competitive cost, can provide useful inputs of power into the grid during the daytime period thus saving millions of tons of fossil fuels in meeting the demand.

In view of the fact that even today solar PV electricity can be produced on a really big scale efficiently and at competitive prices in several parts of the world which enjoy high levels of solar radiation, the scope of transferring cheap solar power from one country to another, from one sunny region to a cloudy geographical area, is extremely challenging while at the same time presenting many technical and financial attractions. The concept of ‘Project Helios’ which is the transmission of vast amounts of solar generated electricity from sunny Greece to cloudy northern Europe, although fascinating as an idea it requires a considerable amount of study and planning and the mobilization of a large number of companies, at both technical and financial level, if it is to be implemented.

The authors of this assessment study in their desire to understand how 'Project Helios' might or might not work, based on the stated assumptions and plans as put forward by the Greek government, have undertaken the task of analyzing the whole project and its lengthy set of parameters. The concept is definitely worth pursuing since given the right financial and power generation and transmission conditions it could indeed, in few years, provide much needed electricity to Germany and other neighbouring countries at competitive prices.

Moreover, the transmission system is a challenging part of the project which is of high strategic importance for Greece. Finally, the proposed project has a strong European dimension and the study clearly shows the steps towards its implementation with the expected benefits.

Executive Summary

An overview of the solar photovoltaic technology and the trends in Europe and the USA show that the cost of equipment will gradually decrease over the coming years and solar PV power generation will compete with fossil fuel power generation by 2020 in the sunny belt countries. During this period, solar PV power generation will be able to participate in the electricity markets, as it happens today for wind power generation in some countries, with benefits to the electricity sector and the consumers. Grid parity for solar PV in Europe is fast approaching and is most likely to be achieved during the current decade, starting from the southern European countries. Thus, net metering can be introduced for solar PV power generation in the urban environment avoiding any additional charges to consumers. The deployment of PV technology is well developed worldwide with expanding markets and manufacturing capacity.

The harmonization of the Greek PV and in general of the RES market with other markets in the EU, both in terms of the legal framework and the feed-in tariff system, must be carried out as soon as possible. The continuation of the current feed-in tariff regime with long-term contracts of 20 to 25 years in conjunction with the 40% target for RES penetration by 2020 will create serious problems in the operation of the electricity market and will have a severe impact to the electricity sector, the economy and the consumers.

The deregulation of the electricity market in Greece has been inexcusably delayed although there are some signs in evidence of removing the existing barriers in order to establish and operate a competitive market according to the EC Directives. However, the domination of the RES tariffs for a long period based on political decisions alone and the mandatory dispatching of RES power generation will jeopardize the electricity market, maintaining rather than disbanding a regulated electricity market. Moreover, the charges to the electricity bills due to the high feed-in tariffs of RES with long-term contracts combined with the ambitious target for high RES penetration should be seriously reexamined. The feed-in tariff scheme is a temporary tool contributing to the development of technology and the market until the competitiveness of RES power generation with that from fossil fuels can be achieved. The restructuring of the legal framework for RES and a rational feed-in tariff scheme based on best European practice is urgent and absolutely necessary.

"Project Helios", which is heavily promoted by the Greek government and where the involvement of the state in such business is a prerequisite, is based on some overestimated and oversimplified assumptions, deviating from the logic of market forces and the rules of the electricity market in general. The Greek Ministry of Environment, Energy and Climate Change (YPEKA), dreaming to partake in big PV business has set an ambitious target in order to earn money by imitating the practices of PV investors. But the investors are motivated and activated in the local market within the legal framework which has been created by the Ministry. However, this local business model in PV applications is not applicable for export purposes.

The participation of the Greek state by 30% in the project without a cash contribution and the setting of the selling price of the solar PV power generation at 0.22€/kWh, according to the feed-in tariff in Germany (2011) are far from reality. On the basis of the parameters adopted by the Greek government the project is simply not bankable. There are no prospects for the realization of "Project Helios" as it has been announced and consequently, the objectives for any sizeable contribution towards minimizing the Greek debt cannot be achieved. However, a new Helios project based on technological developments and market forces can be developed with a positive long-term impact to the economy and mutual social and economic benefits for the producers and the consumers.

The idea of exporting solar PV power generation from Greece to the central European countries is ambitious but nevertheless it seems to be realistic for implementation on a mid-term basis. Consequently, a joint venture mainly by Greek and other European companies should be established for the project. The transmission of energy to the central European electricity markets is the main issue for further investigation. The electricity systems' interconnection of southern Greece to north Italy by HVDC system and submarine cable is of high importance for Greece and Italy too and for the central European countries' systems as well. The export of electricity produced by wind and natural gas should be considered for better exploitation of the transmission capacity, leading to an increase of the capacity factor.

The interconnection by HVDC and submarine cable between Crete and Peloponnesus will further contribute to the exploitation of solar and wind energy in Crete and also help substitute oil for electricity generation on the islands. In addition, this transmission system will facilitate the interconnection of Cyprus to Greece by HVDC and submarine cable in order for Cyprus to reach the European electricity markets for export of solar PV electricity and by natural gas too, instead of transmitting natural gas by submarine pipelines to the European markets.

This interconnection should be part of the super-grid in south Europe and part of the European highway electricity network for the integration of the national electricity transmission system with support by the EU. In general, this is an interconnection of South-East Europe to central Europe corresponding to the RES features. The prospects for technological and economic feasibility seem to be very attractive with high expectations. Therefore, on the basis of the results of a prefeasibility study for this project, coordinated actions must be undertaken by Greece on a political level in order to obtain support by the EU, and on a business level by attracting investors and providing some incentives.

Thus, an initiative for a new Helios project based on technological and business prospects in a competitive electricity market must be elaborated carefully and launched by the Greek government with strategic goals in power systems interconnecting and exporting of solar PV power generation to central Europe. Due to the considerable technological and financial demands for the operation of the complete project implementation plans should be scheduled for 2020.

This assessment study starts with Chapter 1, which is background regarding the development of solar PV technologies and in Chapter 2 the evolution of PV applications in Greece is described. A brief description of “Project Helios” is made in Chapter 3 and a critical assessment for the prospects for its realization and its effectiveness as well. In Chapter 4, the answers to the question of exporting RES electricity from Greece to the central European countries are given. Finally, in Chapter 5 the conclusions of this assessment study are presented.

1. Background

1.1 The evolution of PV technology and trends

Solar energy is the most highly distributed renewable energy source. It can be used for domestic hot water systems and for space heating, while for solar cooling the technology is close to entering the market. Passive solar techniques and bioclimatic architecture can be successfully introduced in the building sector. Sunlight techniques are very attractive for day lighting in the building sector, too.

Solar photovoltaic is considered as the ultimate technology for power generation. Without moving parts, noise and emissions, the direct conversion of solar radiation to electricity is be achieved. The PV systems can be developed in small sizes up to large sizes due to the modular form of the technology. This technology can be successfully integrated in the buildings' envelope for applications in the urban and rural environment. For large PV plants, large areas of land or roofs are needed without shading.

1.1.1 The PV development in Europe

Today, solar PV technologies present a high potential for development with good prospects for successful results in terms of higher efficiency and lower cost. The solar PV power generation competitiveness with grid electricity, "the grid parity", can be achieved in some southern European countries early in this decade starting from Italy in 2013 and then spreading across the continent by 2020. The PV market in Europe is well-developed and high rates of applications have been achieved during the last years. The solar PV contribution to the electricity demand in the EU by the end of 2011 is estimated at 2% (60TWh), which represents almost the total annual electricity consumption of Greece. New PV markets for a variety of applications are being developed worldwide, mainly in the Asian countries with high manufacturing capacity.

In comparing PV with Concentrated Solar Power (CSP) technology it must be pointed out that CSP applications require large flat areas of land for their development as they require the construction of central power plants of high capacity. Therefore, large areas of land in Mediterranean countries are needed for such solar plants (Southern Europe and North Africa) while the scarcity of water may be an additional difficulty in the development of Solar Concentrated Power. This technology offers the possibility for heat storage in order to extend the power generation time during the evening hours. Some large plants are in the planning or implementation stage in Spain and Morocco. However, the potential for improvement of their efficiency and the economics of CSP technology is limited with power generation costs higher when compared to photovoltaic technology.

The targets for the development of PV technology in the EU that are used as the basis for research objectives, together with current and historical data are presented in Table 1. The turn-key market price concerns a 100kW PV system and the power generation cost with PV modules at optimum constant angle in Southern Europe with global solar irradiation of 1,800kWh/m^{2}yr. Some other assumptions used are as follows: 80% performance ratio (0.8*1,800=1,440kWh/kW*yr), 1% of the system's price for O&M cost each year, the economic system lifetime 25 years and a discount rate 6.5%. However, by the end of 2011, the turn-key market price for a 100kW PV system was below 2€/W instead of 2.5€/W presented in the Table 1 (today). Moreover, it should be noticed that for high capacity PV plants on the ground the relevant figures should be significantly lower (about 1.6€/W turn-key price at the end of 2011).

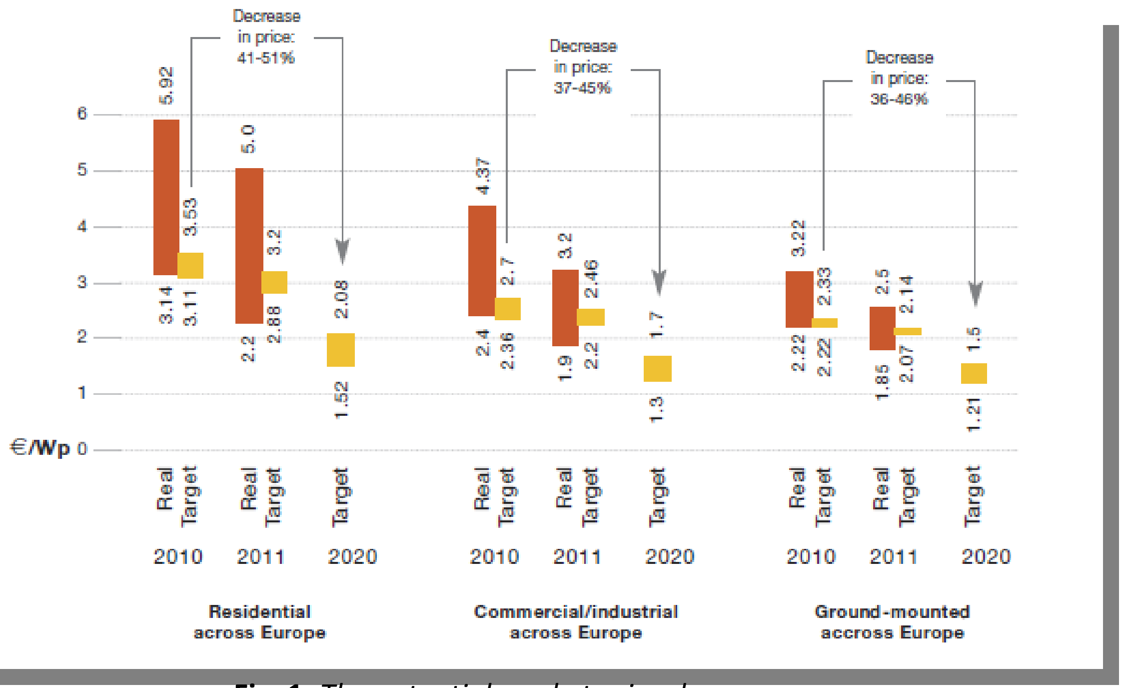
Table 1: *Evolution of PV technology and targets (EPV/TP-SRA 2nd edition, 2011)*

	1980	TODAY	2020	2030	LONG TERM POTENTIAL
Typical turn-key price for a 100 kW system (2011 €/W, excl. VAT)	>30	2.5	1.5	1	0.5
Typical electricity generation costs Southern Europe (2011 €/kWh)	>2	0.19	0.10	0.06	0.03
Typical system energy payback time Southern Europe (years)	>10	0.5-1.5	<0.5	<0.5	0.25

Referring to the power generation cost another parameter to be considered is the PV module degradation, which affects the performance of the PV system over its lifetime. In general, the accepted guaranteed performance of PV modules now is 80% of their initial performance after 25 years. The increase in lifetime reflects improvements in degradation ratios over the years with a guaranteed lifetime of 80% of the initial performance after 35 years for PV modules produced in 2020. The same is expected for the inverters, from 15 expected lifetime years in 2010 to 25 years in 2020.

Another assessment for the PV system price evolution in four European countries made by EPIA (European Photovoltaic Industry Association) is presented in Figure 1. The market prices are presented for four market segments and capacities: residential 3kW, commercial buildings/industrial plants 100/500kW and utility scale ground mounted 2.5MW. The real price for ground mounted PV systems at the start of 2011 is presented in the range 1.85 to 2.5€/kWp.

The PV power generation costs in Europe could fall to around 50% until the end of the decade determined by system size and irradiance level. For large PV plants on the ground at the end of 2011 in the lower price range of the market total costs were about 1.6€/W, while the prospects for 2014 are in the region of 1.4€/W or below. On the same basis, the target price of 1.2 to 1.5€/W for 2020 presented by EPIA could be about 1€/W for large PV plants on the ground and 0.06€/kWh PV power generation cost in the southern countries. Similar figures are provided by some reliable institutes.



<u>Fig. 1</u>: *The potential market price decrease*

(Source: EPIA, "Solar PV Competing the energy sector", September 2011)

However, having in mind the huge manufacturing capacity developed outside Europe, the international trade dynamics will have an important impact on the price of PV systems in the coming years. Fluctuations of the US Dollar and the Chinese Renminbi against the Euro could clearly affect PV system prices in Europe. Thus, the continuous decrease depicted in Table 1 must be considered as a trend more than a clear roadmap.

1.1.2 The DOE SunShot Initiative (USA)

In February 2011, the U.S. Department of Energy (DOE) unveiled the "SunShot Initiative", a collaborative national initiative to make the solar energy technologies cost competitive with other forms of energy by reducing substantially the cost of solar energy systems before 2020. It should be mentioned that in 1995, USA held 43% of the world's solar PV market and now only 6%.

The aim of the initiative is to accelerate and advance existing research efforts by refocusing its solar energy programmes to make large-scale solar energy systems. They must be cost competitive with conventional forms of electricity without subsidies and must enable widespread deployment across the United States by the end of this decade. To accomplish this, DOE is supporting efforts by private companies, academia, and national laboratories to drive down of solar PV system cost to about 1$/W with solar electricity cost to about $0.06/kWh. This in turn will enable solar-generated power to account for 15–18% of America's electricity generation by 2030.

The Initiative is well-structured with integrated actions to achieve the goals. The projects of the SunShot Initiative are organized into three categories, which are based on the mission, vision, and goals as follow:

- *Reducing Solar Technology Costs*—projects that reduce costs related to photovoltaic and concentrating solar power technologies,
- *Reducing Solar Grid Integration Costs*—projects that reduce the costs of connecting high penetrations of solar electricity onto the grid, related to balance of systems, power electronics, and smart grid, and
- *Accelerating Deployment*—projects that remove market barriers, specifically related to fostering a skilled workforce and standardized permitting and interconnection.

Seamless integration of solar energy into the electricity grid, while ensuring grid reliability and stability, is vital to the Department of Energy SunShot Initiative, and enabling widespread adoption of this clean, renewable energy source across the USA. Innovative, cost-effective solutions are required to make it simple, safe, and reliable for solar electricity to be fed into the grid. DOE collaborates with the solar industry, utilities, and national laboratories to address the technical and cost barriers to connecting large-scale solar energy systems into the grid. By eliminating barriers across federal, state, and local lines, deployment of solar technologies can be mitigated and power grid integration optimized.

1.2 The EU Energy and Environmental Strategy - National PV targets by 2020

The EU strategy aims in helping the development of energy systems through improvements of their security of supply and sustainability, while the penetration of renewable energy sources seems to be an ambitious goal. The new EU Strategy for competitive, sustainable and secure energy was released on 10th November 2010 and highlights the objectives adopted in the last EU summit conference for energy and the environment of March 2007. The general objectives refer to the limitation of the global average temperature increase to not more than 2°C above the pre-industrial level by the year 2100 and they are related to the security of the EU economy in terms of energy and to the competitiveness of the EU economy regarding technological progress. These general objectives can be achieved through the specific ones that the European Council has set and include the following goals by 2020:

- The reduction of the EU's greenhouse gas emissions by 20% below 1990 levels,
- Improvement in energy efficiency by 20% and
- A share of 20% of renewable energy in the end-use energy balance and a share of 10% of biofuels in transport

The national goal for Greece according to the EU decision is 18% RES penetration in the end use balance by 2020 but the government has set another more ambitious target of 20.2%. Moreover, another more ambitious target was set in RES electricity generation of some 40% penetration into the electricity systems by 2020, from 13% in 2010.

According to the EU Directive on RES (2009/28/EC), each Member State is called to develop a National Action Plan towards the specific goals. They should also aim towards energy production from renewable sources. A wide range of centralized and distributed energy systems should therefore be considered in applications that exploit renewable energy. In distributed RES systems, the electricity is generated from many small energy sources located within the settlement. Regarding the applications of solar PV technologies there are usually applied on buildings' available surfaces. The increase in small-scale decentralised as well as large scale centralised renewable power generation systems will bring about inevitable changes in electricity infrastructure. Large hydro and flexible power generation by natural gas will contribute in order to cover the power deficit which the intermittent character of solar and wind power generation implies. Thus, the restructuring of the electricity grid in order to absorb the volumes which the 2020 targets entail together with the development of innovative storage technologies. Moreover, new tools and control strategies should be developed for the operation and management of the electricity systems.

Electricity from photovoltaic systems can be well matched to peaks in demand during the middle of the day, when high marginal electricity prices are experienced in some parts of Europe. In Southern European countries, where the seasonal peak in electricity demand occurs in the summer, again the output of photovoltaic capacity is at its greatest.

Table 2: *NREAPs, national PV targets in the EU-27 by 2020 (indicative)*

Country	MW installed	% of Power Mix
Austria	322	0,4%
Belgium	1.340	1,0%
Bulgaria	303	1,2%
Cyprus	192	3,9%
Czech Republic	1.695	2,1%
Denmark	6	0,0%
Estonia	-	0,0%
Finland	10	0,0%
France	4.860	1,1%
Germany	51.753	7,4%
Greece	2.200	4,2%
Hungary	63	0,2%
Ireland	5	0,0%
Italy	8.000	2,6%
Latvia	2	0,0%
Lithuania	10	0,1%
Luxembourg	113	1,3%
Malta	28	1,4%
Netherlands	722	0,4%
Poland	3	0,0%
Portugal	1.000	2,3%
Romania	260	0,4%
Slovakia	300	0,9%
Slovenia	139	0,9%
Spain	8.367	3,8%
Sweden	8	0,0%
United Kingdom	2.680	0,6%
TOTAL EU	84.381	2,4%

According to the National Renewable Energy Action Plans (NREAPs) related with the RES targets for 2020 in the EU-27 countries, the total installed capacity is more than 84GW with a total contribution of 2.4% in electricity demand by 2020 (Table 2). An ambitious target has been set by Germany with 52GW installed PV capacity in 2020 with 41.4GWh/y power generation, followed by Spain with 8.4GW and 14.3GWh/y. Italy has already surpassed (in 2011) the national PV target for 2020 by about 50%. The highest PV power penetration in 2020 is expected for Germany with 7.4% followed by Greece with 4.2%. In Table 2, the national indicative PV targets in the EU-27 are presented. However, a 6% PV penetration in the EU-27 electricity networks is considered by EPIA, as a realistic target for 2020, instead of 2.4% in Table 2.

1.3 The rise of photovoltaic applications

The recent rapid market growth shows that PV can make a significant contribution by 2020 and continue to grow thereafter. It is estimated that by 2020 PV it may contribute up to 4% of the world's electricity demand and 9% by 2030. In addition, PV requires no water in its operation and it is compatible with dual usage of land, when applied in rooftops or when installed on raised support structures on grazing land. Since PV is deployable within Europe, it can play an important role in improving the security of Europe's energy supply. Moreover, PV is very well suited to providing access to electricity in rural areas.

By the end of 2010, around 40GW of PV was installed worldwide, with about 75% of that capacity in Europe (EPIA 2011). According to recent data the total global installed PV capacity exceed of 67GW at the end of 2011. It should be noted that the far biggest market for PV applications is in Europe while Asian countries have developed a huge PV manufacturing capacity (see Fig. 2). In terms of newly installed power generation capacity in Europe, PV was the largest renewable energy source in 2010, followed by wind and second only to gas. The annual global PV cells shipments in 2010 were over 27GW in comparison to 12.5GW in 2009 (an increase of 118%). The manufacturing capacity rose from 20.4 to 36.6GW/y over the 12month period in 2010.

This impressive growth is due to successful market development policies in several countries, but most notably in Europe. Global annual revenue of about €44 billion in 2010 is estimated, where around half of this is related to modules revenues. Projecting to 2020 for an annual PV market size of around 135GW, as forecast in EPIA's "paradigm shift" growth scenario, global annual revenue is estimated at €135 to €200 billion. According to EPIA, 50-55% of the total value of a PV system is created close to the end market, where the system is installed.

Future solar PV applications, in distributed or centralized plants, should be combined with the relevant storage facilities. The storage will contribute to the efficient management of the electricity systems to successfully meet the demands and improving the penetration of solar PV energy into the electricity network. Batteries of Li-ion technology with high efficiency and long life time could be combined with PV plants, while the battery pack of the electric vehicles can be used as a tool in charging and discharging modes for load and power generation management.

To meet the challenge of this market expansion, the sector needs a diverse and qualified workforce including engineers who can install and maintain PV systems, skilled operators and technicians in high-tech solar factories and researchers for R&D activities. To estimate the employment potential, EPIA currently uses an assumption of 30 jobs per MW installed. Although the labour intensity will decrease with decreasing system prices, the rapid market growth will guarantee a strong increase of the number of jobs in Europe.

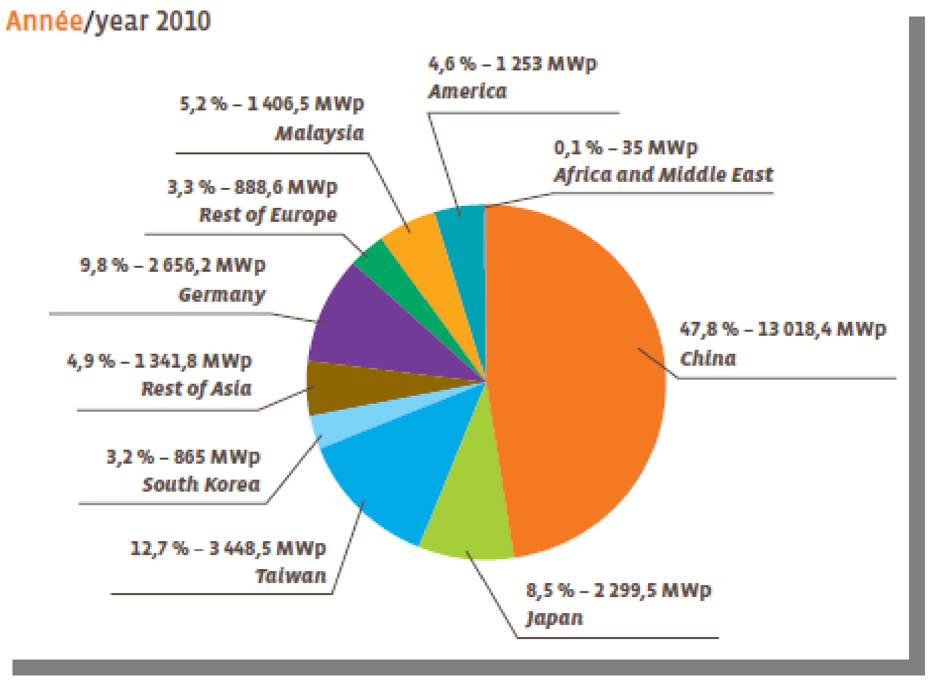


Fig. 2: *Geographic distribution of PV cells production (MW) in 2010 (Source: Photon International/March 2011)*

Asia continues to dominate in global PV cells production with 82.3% output in 2010, while Europe participates with 13.1% and America with 4.6%. From the 10 top PV cells manufacturers worldwide, four are in China, two in Taiwan, two in Japan, one in Germany and one in the USA. In Fig. 2, the geographic distribution worldwide of PV cells production in 2010 is presented.

The total PV installed capacity in the EU-27 by the end of 2010 was about 30GW, from which more than 13GW was installed in 2010 alone. Germany is in the top with about 18GW (7.5GW in 2010), followed by Spain, Italy, Czech Republic and others. In Germany, about 900,000 PV units are in operation, mostly in the size between 2 to 40kW installed in the urban environment and connected to the low voltage grid.

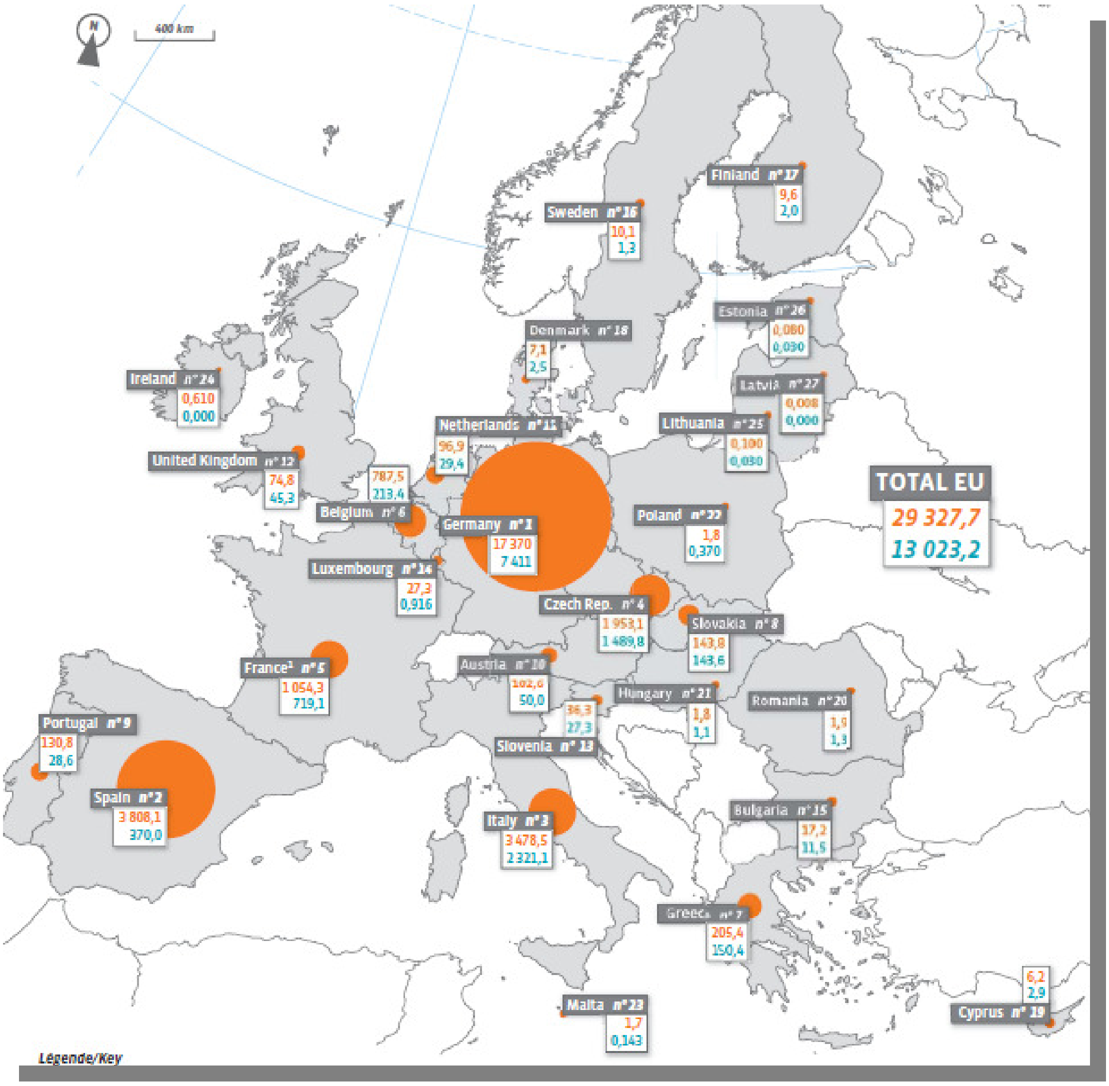


Fig. 3: *PV total installed capacity by the end of 2010 in MW, (source: Eurobserver)*

During 2011, the rise of some new markets in the EU stands out. Italian solar PV market became one of the largest followed by the German one, immediately after introducing an incentive system in 2007. In May 2011, the Italian government reduced the feed-in tariffs as to sustain customers. According to the chairman of industry body GIFI, Italy's total PV installed capacity could rise to 12.0- 12.5 GW by the end of 2011, while the growth will slow in 2012. The total annual cost of incentives is estimated at 4.9 billion Euros for a total installed PV capacity of 11 GW and around 288,000 PV plants on stream. Total amount of PV installations is likely to increase to nearly 350,000 by the end of 2011.

The rise of the PV market in Greece is presented in the relevant chapter. In Figure 3, the status for PV applications in the EU-27 are presented in a map. The figures in red indicate the cumulative installed capacity and in bleu the installed capacity during 2010.

2. The Evolution of PV Applications in Greece

The rise of the PV market in Greece started essentially in 2006 following the introduction of a new law. Law N3468/27.06.2006 provided high tariffs for PV power generation and subsidies by public money for the investment of about 40% up to 60% of the investment cost. Before 2006, the framework for RES applications, including PV, provided a uniform tariff for all renewable sources and different subsidies for the investment. Despite the high subsidies for PV, the applications were very limited because their economic viability was marginal.

The new law in 2006 focused on good business only and not on the creation of a sustainable PV market in the country by exploiting the PV benefits and the favorable solar potential. The lack of considerations for social and economic benefits in long-term was the major disadvantage with negative impacts to the electricity sector and the economy. Although the feed-in tariff (FIT) is a valuable tool for more advanced policy for the creation of a sustainable PV market, maximizing the social and economic benefits, in the case of Greece was only aimed at businesses with lack of transparency in the tariff's formation. Two tariffs were provided for PV plants with 20 years contract, below 100kW and above 100kW promoting large applications on the ground. Small PV plants in the urban environment for household PV, BIPV or roof PV applications were almost prohibited.

The bloated bureaucracy of the country, despite the high feed-in tariffs, has ensured a low rate of PV applications, avoiding the case of Spain with a boom in PV applications and negative impacts to the local PV market. Until recently the licenses of power generation for RES applications were granted by the minister who also approved the subsidies for the investment as well. The trading of licenses in the open market with prices close to 20% of the value of the investment, in conjunction with the bureaucracy, with long delays for granting the construction license of up to three or four years, discouraged local and foreign investors in Greece and so the low rate of applications is explained.

Subsequently some improvements in the law have been made but were based on the same concept. Meanwhile politicians like to promote the great opportunities for PV business (and in general for RES) in Greece which still offers the highest feed-in tariffs in Europe.

2.1 Legal framework and applications

Law N3851/04.06/2010 concerns the acceleration of RES deployment in order to face the global climatic change with references to some articles of the previous law N3468/2006 and certain modifications.

This law introduces the farmers' PV plants of 100kW capacity with supporting measures aimed at increasing their incomes by planting PV modules in the farms instead of pursuing agricultural activities.

For PV plants below 500KW no license for power generation is required. Household PV applications have been introduced with capacity up to 10kW and with simplification of procedures as well.

However, the revision of the building codes for Building Integrated PV (BIPV) and installation on the roofs has not yet been carried out, which often creates serious problems in the applications on existing or new buildings. The time needed for the administrative procedures for large roof integrated PV installations in the case of new buildings require a multiple of the time needed for granting the building construction license together with the construction time. This is a drawback in the use of large roofs of new buildings and forces the applications to the ground using valuable land area for long-term periods.

The complexity of the environmental regulations has nothing to do with the PV technologies while it requires some odd procedures consuming time and money. Meanwhile, the trading of PV licenses still continues with significant costs to the investment. The high PV tariffs sufficiently absorb the transaction cost of licenses and the use of expensive agricultural land as well.

The connection of PV plants to the grid became a serious problem with adverse impact in the development of the market. Clearly there is a gap in the law while there is to not much willingness by the government in facing the problem. Most of the PV plants are connected to the distribution grid in the low or medium voltage grid. Unfortunately, as yet there is no distribution system operator (DSO) because the unbundling of the national utility has been considerably delayed. The lack of the appropriate structure and the necessary grid codes has also a serious negative impact in the connection time and the relevant high costs compared with other DSOs in other countries. The introduction of the farmers' PV plants creates a heavy task for the utility in extending far the medium voltage grid in order to connect the farms with new substations for the 100kW PV plants.

Another problem is the very conservative position adopted by the utility in the penetration of the dispersed PV plants, stating reasons of grid saturation in order to avoid any possible instability in the operation of the system. This is also the reason given for the very low PV penetration in the islands' systems which is a priority area for PV applications.

The Ministry has by law introduced an ambitious target of 40% RES penetration into the electricity sector by 2020, through high feed-in tariffs. Both the target and the feed-in tariffs are oriented mainly to business, without any assessment or investigation for the operation of the whole market, the required measures and infrastructure and the relevant impact to the electricity sector at large, the economy and the consumers. The political decision is to achieve the target as soon as possible without any consideration for the side effects to the economy and to the development of the market in a balanced way.

Recently, "fast track" procedures for investments of strategic importance were introduced by ministerial decree for speeding up procedures or skipping them altogether in the case of large PV plants. The high PV tariffs in Greece linked to a twenty year contracts attracted many investors to build large PV plants of hundreds of MW doing good business without risks. However, there are questions about the criteria used to evaluate investments for large PV plants considered to be investments of strategic importance for the national economy.

According to the data provided by the Ministry, the total installed PV capacity in Greece by the end of September 2011 was 460MW with trends to reach 580MW by the end of the year, compared to 198MW at the end of 2010. The total PV capacity of signed contracts by the end of September, locking the price of feed-in, was about 2,000MW with increasing trends, therefore exceeding the national target for PV of 2,200MW by 2020. In addition, the total capacity of projects with construction licenses was 370MW and of the projects with grid connection option 3,220MW. Thus, by the end of September 2011 the total PV capacity in the way for realization exceeded 6,000MW out of a total capacity of 11GW of submitted applications. This must be compared to the national target of 1,500MW in 2014 and 2,200MW by 2020. It seems that the Ministry is very happy seeing the excess of the national targets but without any consideration consernig the impact to the consumers, the environment and the economy.

According to the law, through the signed contracts the feed-in tariff is locked over the next 18 or 36 months, a period dedicated for the implementation of a PV plant. The best practice in the EU is the adoption of the price in place during the connection of the complete PV plant to the grid. From another aspect, this situation in Greece contributes to the trading of licenses during this period with better results, while the implementation of the project could be postponed to the end of the period, with the prospect of lower prices for PV plant equipment. This is a peculiarity of the Greek law oriented to good business.

From the 11GW (September 2011) total capacity of the submitted applications some 50% (about 5.5GW) includes large PV plants of MW-scale. The substantial decrease in the price of PV equipment in the market over the last two years, and the high PV tariffs are the driving forces for the increased interest in PV applications and the focus on large plants on the ground.

Table 3: *Installed PV capacity by size of PV plants*
(Data provided by HTSO for the grid connected PV plants)

PV size	By 31 December 2010		By 31 December 2011	
	MW	%	MW	%
≤ 20kW	23	15	48	11
20 to 150kW	79	52	178	40
150 to 2,000kW	26	17	130	30
>2,000kW	25	16	83	19
Total	**153**	**100**	**439**	**100**

From the evolution of the PV applications it seems that the trend is towards larger PV plants installed on the ground. The low percentage of small PV plants (<20kW) should be pointed out.

According to the National Renewable Energy Action Plan for Greece, the estimated installed capacity for power generation by PV technologies is 2,200MW by 2020. The distribution of this amount to various categories between 2014 and 2020 is presented in Table 4.

Table 4: *Estimated installed PV capacity between 2014 and 2020 (NREAP)*

Category of applications	2014 (MW)	2020 (MW)
Applications by farmers	500	750
Applications in buildings	200	350
Other Applications	800	1,100
Total	**1,500**	**2,200**

About 2/3 of the capacity is scheduled for implementation as early as 2014, while the PV grid parity is expected for Greece by the middle of this decade. The rest, i.e. only 1/3 of the capacity, is scheduled for the period 2015-2020, where lower PV prices are expected. Thus, it seems that the policy of the Ministry is favoring big investors and is oriented towards business rather than to the social and economic benefits. As it is already mentioned, the national PV target for 2020 has already been surpassed in the form of signed contracts by the end of 2011, mainly by large PV plants.

Moreover, three large PV plants of 458MW total capacity are supported for implementation through the fast track tool, using the existing high tariffs with 20 years contracts. However, these large PV plants should really be scheduled for the end of the decade with low power generation costs and prospects for them to participate with their solar PV power generation in the electricity market, without feed-in tariff and additional charges to the consumers.

2.2 The Feed-in Tariffs for PV applications

The current feed-in tariffs for RES (law N3851/2010) are based on figures given in law N3468/2006 with slight modifications but within the same concept. A new figure for household PV (<10kW) has been added and the gradually falling prices (every six months) for all other new applications as well, independently of the rapid reduction of prices for PV equipment. However, it seems that all these figures are not based on an economic analysis with inputs from the market. In general, the feed-in tariff figures for RES as included in laws of 2006 and 2010 with their ambitious targets are characterized by total lack of transparency. The tariffs have been adopted without any assessment study and their impact to the consumers and the economy. In addition, there is not any monitoring mechanism in place regarding RES applications and their impact to the economy and society over the next 20 or 25 years taking into consideration the contracts in force. Without such a mechanism it is impossible to have a complete picture of the market or to be in a position to take any measures deemed necessary.

Table 5: *Greek Feed-in tariff for PV power generation in €/MWh*
(data until January 2012)

PV Applications From:	Mainland			Islands' systems	
	<10kW for 25 years	**<100kW for 20 years**	**>100kW for 20 years**	**<5kW for 25 years**	**any capacity for 20 years**
Household*	550€/kWh			550€/kWh	
Aug. 2011		394.89	351.01		394.89
Febr. 2012		375.54	333.81		375.54
Aug. 2012		353.55	314.27		353.55
Febr. 2013		336.23	298.87		336.23
Aug. 2013		316.55	281.38		316.55
Febr. 2014		302.56	268.94		302.56
Aug. 2014		293.59	260.97		293.59
2015…….**		1.4xMSP	1.3xMPS		1.4xMPS

**Reduction 5% every year of the price (0.55€/kWh) for new household PV plants is provided from 01.01.2012 up to 31.12.2019.*
***From 2015, the price is determined on the basis of the average marginal electricity price of the system (MPS).*
Moreover, the above prices are adjusted every year by 25% of the consumer Index of the previous year.

By a Ministerial decision from February 1st, 2012 the above prices (up to August 2014) have been reduced by 12.5% for new PV projects below and above 100kW in the mainland and in the island's systems, and by 5% every 6 months for PV household applications of <10kW (49.5c€/kWh from February 2012). This means that having in mind the capacity of the signed contracts with the locked prices for the next 18 or 36 months, the national PV target for 2020 could be achieved too early by using the previous prices, which are almost close to the prices of the year 2006. The decision is characterized again from lack of transparency and lack of a much needed coherent policy. From another aspect the new Ministerial decision will motivate the trading of PV licenses, which have been issued using the old prices because the situation of the framework with the peculiarities and the wrong policies remain intact with a disastrous impact to PV market and the electrical sector in general.

2.3 The PV industry in Greece

During the last years five PV manufacturing companies have been established in Greece for the production of PV cells and modules based on crystalline silicon technologies and one of them on thin films. The total annual production capacity of these plants exceeds 200MW. The manufacturing units are relatively small, with a capacity between 20 to 60MW/y, addressed mainly to the Greek market but also for exports. However, the competition against the large PV Asian manufacturers is very tough. In addition, the development of the PV technologies and the manufacturing processes in association with the economy of scale leads to even lower production cost in a competitive market. By the end of 2011, some of the manufacturing companies were out of operation, while some others were dealing mainly with the production of PV modules in order to supply their own large PV plants.

2.4 A critical assessment of PV development in Greece

The legal framework comprises of a number of laws and ministerial degrees addressing mostly all RES and not to each individual renewable energy source. The relevant procedures are not clear leading to significant delays and additional costs for granting the licenses. The lack of an integral law and especially provisions for each form of renewable energy source, in that case for PV, must be pointed out.

The consequence of the bloated bureaucracy among others creates the conditions for the trading of the licenses with significant costs to the overall investment cost. In addition, this situation discourages foreign investors to participate in local RES market applications. Hence, the simplification of the bureaucratic procedures involved is of paramount importance and will help reduce the investment costs and consequently it could contribute to the reduction of the current feed-in tariff figures with significant benefits to the consumers and the economy.

The connection of the PV plants to the grid is also a serious problem and this weakness in the framework should be pointed out. A reasonable time for connection should be considered while the transparency of the relevant costs for any extension of the grid and connection is necessary. In addition, the seamless integration of PV plants into the grid for further PV penetration should be adopted by exploiting the features of the new technologies. Thus, innovative technologies with smart grid concepts and storage provisions should be progressively introduced. The unbundling of the national utility, i.e. PPC, and the establishment of a DSO (Distribution System Operator) with the appropriate grid codes is absolutely necessary. Moreover, ancillary services by PV systems to the grid should be included in the grid codes and the regulations, while all the relevant benefits to the network must be evaluated and factored accordingly.

The existing tariff scheme with high figures and lack of transparency is a very crucial problem with serious impact to the economy and the consumers and thus, coordinated efforts are needed to change the structure and the actual figures of the tariffs. The feed-in tariff system is a valuable tool for policy, and greatly contributing to the development of RES and maximizing their benefits. However, this tool can only have a provisional character with its main target being the assistance in the development of RES technologies and the market in order to compete eventually with conventional energy sources. The main objective is to create a sustainable PV market with reasonable feed-in tariff figures, supporting also the local PV manufacturing companies. According to lessons learned from Spain and the Czech PV markets, high PV tariffs, at the end, kills the PV market and the local industrial activities with negative consequences to consumers and the economy alike.

A well-designed feed-in tariff system with transparency is a very useful tool for the appropriate policy to maximize the social and economic benefits. The poor structure of the FIT regime in Greece for PV includes only one type of application (the household) with all others divided in two capacity sizes (below and above 100kW) without cap, which leads to large plants on the ground with significant consequences to the economy and the society. The benefits of the PV technology are not well-exploited by the existing framework and the feed-in tariff scheme currently in force. In the current period priority should be given to the dispersed PV applications in the urban environment, instead of agricultural type PV plants and large capacity ones, maximizing the social and economic benefits.

The dispersed PV plants in the urban environment, such as PV roofs and BIPV, offer more benefits without the need for extension of the grid, creating a sustainable PV market and a number of new jobs. In the National Plan only 20% of the national PV target is dedicated for PV in buildings but the trends are showing a lower figure of around 10% at the end, because FIT is promoting the PV on the ground with large capacity PV plants. In other countries the policy is the exact opposite with 80% to 90% of the PV applications in the building sector and the creation of thousands of new jobs. Most of the 900,000 PV plants and the highest part of the 18GW in Germany (data for 2010) are between 2 to 40kW capacity connected to the low voltage grid in the urban environment.

In this period it seems necessary to put a cap in the size of the PV plants on the ground, or through the feed-in tariff system promoting dispersed PV applications in the urban environment and discouraging large PV plants, in order to protect the consumers from higher bills and at the same time improve the competitiveness of the economy. Large PV plants of megawatt and multi-megawatt size must be postponed until the end of the decade following the expected grid parity and when the PV power generation costs will reach the competitiveness of the electricity sector. Therefore, the feed-in tariff system should be redesigned in order to help the PV power generation to compete in the wholesale electricity market.

Today, in Greece, there is a long time interval (18 to 36 months) between the applied price in the contract and the connection of the PV plant to the grid. During this period significant changes in the prices of the PV equipment are expected due to the development of the technologies and the PV markets. This is the reason for the frequent revisions of the feed-in tariffs for PV applications, every year or twice per year (Germany). Thus, taking into account that the erection of a PV plant takes some weeks for small and medium size applications and some months for the large systems, the FIT which exists during the connection of the plant to the grid should be applied, which is the best practice in the EU. However, in this case the time period for the connection of the PV plant to the grid must be reasonable.

The high penetration of RES with guaranteed prices for 20 or 25 years contracts will most likely have serious negative impact in the operation of the electricity market. This matter can be resolved through the appropriate design of the FIT system in connection with the contract period in order for PV systems to take part in the competitive market. The continuation of the current feed-in tariff scheme in conjunction with the 40% penetration target for electricity generation in Greece from RES by 2020 will create serious problems in the operation of the competitive electricity market with severe consequences to the electricity sector and the economy.

The deregulation of the electricity market in Greece has been seriously delayed and currently there are some efforts, removing the existing barriers, in order to establish and operate a competitive market during the next years according to recently adopted EC Directives. However, the domination of the RES tariffs for long period based purely on political decisions and the mandatory dispatching of RES power generation will jeopardize the electricity market, maintaining rather a regulated electricity market. Moreover, the charges to the electricity bills due to the high feed-in tariffs of RES with long-term contracts combined with the ambitious target for high RES penetration should be seriously reexamined.

It seems necessary to create a monitoring system for all RES paid through FIT's together with the introduction of a tool for the assessment of the charges to the consumers, something which will contribute to transparency for the proper decisions and the necessary adjustments.

Therefore, a new framework specifically dedicated to PV applications in Greece is proposed together with the design of a new FIT regime based on best European practice. The restructuring of the National Plan (NREAP) with new targets is also suggested, regarding the different types of applications and the sizes of the PV plants, scheduled in the current decade. The ultimate objective should be the development of PV applications on a long-term basis by maximizing the economic and social benefits, the creation of new jobs and the further promotion of construction and manufacturing activities, besides the contribution of clean energy to the electricity sector.

The "grid parity" for PV in Greece is expected to be realized during the next few years. The tool of "net-metering" (the algebraic sum of in and out electricity), mainly for PV applications in buildings and households, could be introduced. This tool offers common benefits to the utility and the consumers alike without the imposition of any additional charge for RES in the electricity bills.

The significant reduction of the prices for PV equipment during the last years led the governments in most of the EU countries to frequent reductions of the PV tariffs, except Greece. The case of Spain in 2008 and later that of Czech Republic with high volumes of installation in a short time period and severe impacts to the economy and the market, should be avoided in Greece.

The current PV tariffs in Greece and in other countries together with the prevailing trends are presented in Table 6 for comparison reasons, taking also into account the differences in solar radiation. In the Greek case the current tariff for PV plants above 100kW (the only tariff) compared with the tariff for large plants on the ground in other countries, has been considered for simplification reasons.

Table 6: *Current feed-in tariffs for large PV plants on the ground and the trends*

Countries	Size (kW)	Contract period y	2011 c€/kWh	2012 c€/kWh	2013 A c€/kWh	2013 B c€/kWh
Germany	any	20	22,07	17.94	16.33*	13.77*
UK	250/5.000	25	10 (8.5p)	10	10	10
Spain	any	20	14			
Italy	>5,000	20	17.2	14.8/13.3	12.1	10.5
Bulgaria	>200	20*	25*			
Turkey	any	12	10+4.7**	10+4.7	10+4.7	
Greece* **	**>100**	**20**				
01.02.				**29.208**	**25.262**	**21.849**
01.08.			**35.101**	**27.164**	**23.494**	**20.320**

Two prices in the box correspond to the first and second 6month periods.

**Scheduled, **c$(13.3+6). ***Adjustment of the above prices for Greece every year by 25% of the consumer Index of the previous year.*

According to the figures in presented Table 6, Greece which enjoyes high solar radiation has the highest tariffs in Europe, today and over the next years, far higher from the northern European countries.

In general, the electricity sector in Greece which faces serious problems in the operation of the electricity market (because of the failure by successive government of opening up the market to competition) due to ill fated political decisions and the ambitious targets set for RES, based on high tariffs, is moving in the wrong direction with severe negative impact to the economy and the consumers. The high RES potential of Greece, especially solar and wind should be exploited by maximizing the social and economic benefits towards a competitive economy for the long-term. The restructuring of the legal framework for RES and the adoption of a rational feed-in tariff system, based on best European practice, is an absolute priority.

3. "Project Helios"

The idea of "Project Helios" was triggered by a statement of Wolfgang Schäuble, the German Minister of Economy, that Greece should exploit the abundant solar energy for export in order to help reduce the Greek debt. Following that, the Greek Ministry for Environment, Energy and Climate Change (YPEKA) developed and presented "Project Helios", in the belief that the birth of "Helios" will save the Greek economy.

3.1 Short presentation of "Project Helios"

The "Project Helios" is dealing with power generation by solar energy through photovoltaic technology exclusively for export. There is not any proper feasibility study or any report available for this large and highly promoted, by the Ministry, project. Nor has a proper engineering study, even at a preliminary stage, been documented. A brief description is made here on the basis of data given by the minister during a series of press conferences.

The concept of the project is the participation of the Greek state in companies of the private sector which are involved in PV business and which will generate electricity for export to Germany or other countries, using the attractive feed-in tariff for a period over 25 years. A huge solar PV capacity of 10GW is envisaged for installation in Greece and the produced electricity, to be exported to Germany through a transmission system, which should be developed.

The share of the Greek state in companies should be 30%, which corresponds to the allocation of land of about 200km^2 for the PV plants and the licensing involved for the project. The selling price was taken as 0.22€/kWh, which was the German feed-in tariff for PV plants on the ground in 2011. A contract for 25 years is to be provided and a net income of one billion € each year for the Greek state is expected. This project is considered by the Ministry as one of the main tools for reducing Greece's dept.

According to the minister, the expected income from "Project Helios" is estimated between 20 up to 25 billion euros over the 25 years of operation from 10GW of PV installed capacity, based on the export of the produced electricity to Germany. It seems that the Ministry, and the Greek government, being very optimistic for the outcome of this project and its anticipated income convinced the European Summit of October, 26th 2011 about the excellent prospects of this enterprise. In paragraph

13 of the Euro Summit statement **/** Brussels, 26 October 2011 (SN 3993/3/11 Rev 3) is mentioned: **"**Greece commits future cash flows from project Helios or other privatisation revenue in excess of those already included in the adjustment programme to further reduce indebtedness of the Hellenic Republic by up to 15 billion euros with the aim of restoring the lending capacity of the EFSF".

3.2. A critical assessment of "Project Helios"

According to IENE's independent assessment of "Project Helios" there are three critical parameters that should be discussed and analyzed in detail which clearly affect the realization of the project and the achievement of its objectives:

- The proposed 30% share of the Greek state
- The feed-in tariff of 0.22€/kWh and the relevant transmission costs
- The time horizon over which the project will be realized.

3.2.1 The 30% share of the Greek state

According to the objectives set by the Ministry of Environment, Energy and Climate Change (YPEKA) the Greek state will participate in PV business together with the private sector but without any cash contribution to the investment. The Ministry intends to offer public or municipal land for 25 years and award the licenses for PV installations, which will thus cover 30% of the total investment cost according to its assessment. Usually the areas for PV installations are considered at zero cost, such as the roofs of buildings or arid land at practically no cost. In case that the Ministry insists on a land cost consideration for the project, this is below 1% of the total investment for a PV plant, according to the prevailing commercial prices of land even for agricultural land.

Regarding the cost for the granting of the required licenses for PV installations, again this is considered almost zero, taking into account that the relevant studies should be part of the engineering of the project. In the Greek PV market and in general for RES-e applications there is an unofficial trading of licenses with sale prices representing about 20% of the investment cost. This situation is due to the bureaucratic and time consuming procedures involved and the existing high PV tariffs. However, such illegal practices cannot be applied in a government sponsored and huge scale project as that of "Project Helios". Currently, large PV projects in the local market are supported through the fast track mechanism for licensee granting without any cost. Therefore, the Ministry cannot sell the license (s) for "Project Helios" in order to participate by 30% in the project. The imposition of a price for awarding the licenses for "Project Helios" is clearly unacceptable and cannot be factored in, especially as it is against EU rules for competitiveness.

Another absurd proposal put forward by the Ministry is that since Greece offers high solar radiation levels, these should be somehow charged and should be considered within the 30% share of the Greek state. Such a proposition in the real market is totally unacceptable because this type of consideration can be translated as an indirect tax for solar use only for "Project Helios", excluding the PV plants already operating in the local market. Therefore, there cannot be any charge for PV applications in Greece since the solar radiation is used as the main "free" input in the assessment of the economic viability of all project.

It is easily deduced that not a single investor will participate in such project with an arbitrary 30% share imposed by the Greek state, which is translated in several billion euros, without any substantial cash contribution from the part of the state while he (the invertors) will have to undertake all risks. Consequently, the real contribution of the Greek state to the investment capital should be assessed below 1% instead of 30%.

3.2.2 The feed-in tariff of 0.22€/kWh and the transmission cost

The feed-in tariff is paid for electricity produced by RES inside the country, because the relevant figures are based on a number of parameters, such as the creation of new jobs, the impaction local construction and manufacturing activities etc. These figures are decreasing year by impact on year as the technology and the markets are being developed, resulting in lower prices for the equipment. In Germany, the price of 22.05c€/kWh in 2011 for PV applications on the ground with twenty years contract will be decreased to 17.94c€/kWh (in Greece it is 35.1c€/kWh almost twice) from the 1st January 2012 and so on every year or every six months. The feed-in tariff is a provisional tool until grid parity is achieved and then the participation of PV generation in the competitive electricity market will be initiated.

From the outset power generation from "Project Helios" was addressed to the German electricity market and maybe to other consumers in central Europe. An additional charge to power generation costs is the transmission costs and the transmission losses. Currently, the available transmission capacity for the operation of the market by the existing interconnection infrastructure through the Balkan countries and through Italy is about 1GW and by 2020 this should be increased to 2GW when planned grid interconnections will be realized. Therefore, only a small part of the 10GW capacity could be transmitted to central European electricity markets through the existing or planned transmission system.

An upgraded and expanded transmission system based on HVDC technology with additional budget could be proposed. Thus, the final cost of the complete project and the eventual electricity price to the German consumers emerge as crucial parameters for the economic viability of the project.

However, today large uncertainties exist in the crucial economic parameters of "Project Helios". It is not at all obvious that the imported PV electricity to Germany from Greece will be paid on the basis of the feed-in tariff system. The passing of a new law by the German Parliament for this case (as the Greek Ministry (YPEKA) is widely expecting), by adopting a feed-in tariff scheme for the importation of Greek solar PV electricity over 25 years with additional charges to the consumers and the economy, by-passing the competitive electricity market is simply not a realistic proposition. Consequently, the imported PV electricity in Germany should be paid through the local competitive electricity market. However, such this possibility, regarding the entry of the PV power generation in the German and European electricity markets would only be effective by 2020, expecting a competitive solar PV power generation cost meanwhile.

Finally, the total cost of PV power generation from "Project Helios" and its transmission to the German electricity market must be realized on a competitive basis. The project comprises 10GW PV of plants and the same capacity for the transmission system, which is translated into a huge investment capital with considerable uncertainties in financing and technical implementation.

3.2.3 The time horizon for the realization of the project

"Project Helios" is a huge power generation and supply project consisting of solar PV power generation of 10GW installed capacity while it requires a huge transmission system of the same capacity connecting Greece and Germany. The design phase is very demanding with regard to the technical aspects and the time involved, especially for the transmission system and the necessary optimization work that needs to be undertaken. The realization of total capacity of 10GW PV power generation and the relevant transmission system can only be undertaken on a step by step basis and based on an appropriate time schedule. The time needed from the beginning of the design phase until the commissioning stage of the completed plant is estimated to be about 10 years, which is beyond 2020.

3.3 The outlook for "Project Helios"

The Greek Ministry, dreaming to partake in big PV business has set an ambitious target in order to earn money by imitating the PV investors. But the investors are motivated and activated in the local market within the legal framework which has been introduced by the Ministry. However, this local business model for PV applications is not applicable for export purposes.

The contribution of the Greek state to the investment capital of “Project Helios”, through the contribution of public land for PV plant installation, is assessed below 1% of the total investment cost, in the best scenario, instead of the proposed 30% which the Ministry proposes for charges corresponding to licensing facilitation and the “purchase” of freely available solar radiation. The 10GW solar PV project and the corresponding transmission system need a huge investment capital where the participation of the Greek State corresponds to several billions Euro, which under the current economic situation is simply not realistic. Moreover, the uncertainties surrounding the project financing by the private sector and the technical/implementation risks must be considered.

The crucial parameter of “Project Helios” is the selling price to the German market of the solar PV power generated in Greece. The feed-in tariff prices with decreasing trends are paid in Germany for local solar PV power generation and not for imported energy. Thus, there is no case for selling electricity on prices based on the current feed-in tariff for 25 years. The imported PV electricity in Germany should be paid in prices through the local competitive electricity market, which is expected to be effective for the solar PV technology by 2020.

Another important aspect is the time needed for the implementation of such a huge project. It is estimated that about 10 years are needed from the beginning of the design up to the commissioning of the project and thus, the effective time of operation of the plant is beyond 2020.

Taking into consideration all the above crucial parameters and especially the uncertainties surrounding the sitting of the PV plants and the sale and transmission of the generated electricity it is concluded that the realization of this huge project is impossible under its present terms of reference and therefore the objectives of “Project Helios” cannot be achieved. Thus, the prospects of “Project Helios” and consequently any contribution of this project to the reduction of the Greek debt are completely unrealistic.

According to competent analysts, employed by European financial institutions, who have examined the Ministry’s proposals for “Helios”, the project as it stands is simply not bankable. According to their assessment there are no clear indications as to who the buyer of the exported electricity is and who is the seller. Under current legislation in Greece the electricity system operator (HTSO) cannot grant a license for exporting RES generated electricity since this is already heavily subsidized by the Greek state and is by law totally absorbed by the grid. Changing the law to allow RES electricity exports means that the HTSO will have to stop paying FIT's on a preferential basis, thus complicating further the trading environment and creating an unnecessary split between RES electricity producers. At the same time the German TSO has informed Germany's Economy Minister that it is in no position, under the existing RES legal structure and operational procedures, to pay for RES electricity imports with present day or future FIT's, as it is obliged to purchase only locally produced RES electricity. A position which is unlikely to change in future as long as FIT's are in existence and Germany can tap easily electricity imports from neighbouring countries at competitive prices.

Legislators at the Bundestag point out that if the law was to change to allow for imports of RES electricity generated in Greece, then the same law should allow RES imports from other EU countries notably Italy, France and Spain which also enjoy good solar radiation regimes. However, German political parties are not prepared to back any government plans for subsidizing solar generated electricity outside Germany.

However, a new "Helios" project based on advanced and innovative technologies and funded entirely by market forces can be developed with positive impact to the economy and mutual long-term social and economic benefits for both, the producers and the consumers. Electricity produced by such a project could then be exported and sold to other countries only at competitive prices through participation in the wholesale electricity market.

4. Can Solar Energy be Exported?

4.1 The new era of electricity and objectives

The electricity sector enters a new era with high penetration of RES into the future electricity networks. The EU-27 target for 20% share of energy from renewable sources in gross final consumption of energy by 2020 led the member states to set ambitious targets for RES-electricity penetration into the networks. Moreover, in some cases besides the EU national target for RES, new policies are being formulated in several countries in dealing with more RES after the Fukushima nuclear disaster.

The initiative of the Desertec project has set ambitious targets for solar energy exploitation in the extensive deserts in the countries of North Africa and the Near East with the creation of an extended super-grid to supply Europe with solar electricity. In view of the political instability in these countries and the harsh conditions prevailing in the dry deserts, it seems that the interest has now moved to the southern European countries. The idea is ambitious but realistic for implementation in mid-term.

In Europe wind energy is considered favourable for exploitation in the central and northern countries, while solar energy is abundant in the southern countries. There are good prospects for solar PV power generation regarding the technology development and the competitive cost, especially for the sunny belt countries.

It is expected that by the end of this decade, the electricity cost based on fossil fuels will be increased due to environmental restrictions and charges for CO_2 emissions, while solar PV electricity cost will be decreased and become competitive with conventional power generation. It is widely foreseen that over the next ten years the new challenges in the electricity networks will be the zero net energy buildings and the electrical vehicles. Thus, RES generated electricity and the networks, through innovative technologies, must satisfy the demand with high quality power supply.
Moreover, new electricity transmission and distribution lines, new substations and strong interconnections between the national transmission systems in Europe are needed for the operation of the electricity market on a competitive basis and for high penetration of RES. The operation and management of the future electricity systems and the new regulations regarding the operation of the markets with high RES penetration are the challenges to be considered.

An integral action plan towards the future electricity grid with high RES penetration should be developed on national, regional and European scale. It means that the development and deployment of RES technologies, especially for wind and solar, should be combined with the development and management of the future electricity networks. Over the next ten years the participation of RES in the electricity market is expected instead of the feed-in tariff system, which is used today for the deployment of RES technologies. All these actions are capital intensive and require new investments and time. Some items for further analysis are briefly presented below:

- Specific studies and further research activities for optimum solutions with innovative technologies for the integration of RES into the operation and management scheme of the networks with high RES penetration and for the operation of the electricity market as well.
- Development of the appropriate policy and new regulations for the operation of the electricity market under the new conditions, including grid codes for RES integration and for the ancillary services provided by RES technologies.
- Development of advanced tools and models for the forecasting of wind and solar output, needed for the operation of the system with high RES penetration and the operation of the electricity market.
- A huge capital and financing models are needed for the new investments in the electricity sector, especially in the networks and innovations, on a national and European level to meet the targets.
- The crucial question is who will pay for the investments and who will be burdened with the cost: the grid operator through the consumers, the RES investors or national and European funds, because the total cost cannot be absorbed only by the market.
- Probably, a new legal framework would be necessary to speed-up all the relevant actions by removing the obstacles, in order to realize the necessary projects (e.g. transmission lines, innovative technologies) in time.

Several European countries meet successfully some of the above requirements but in some others the ongoing eurozone crisis and the associated problems with financing may delay the necessary investments.

Regarding the idea for solar PV power generation in Greece and electricity exports to central Europe, especially to Germany, a new project Helios based on advanced and innovative technologies and the market forces can be developed with a positive outcome to the economy. The project can be split into two parts, the PV power plant and the transmission system, with further investigation of the economic and social aspects.

4.2 The 10GW PV plant

4.2.1 PV technology and type of installation

The wafer based crystalline silicon PV technology (single or poly crystalline and ribbon c-Si) with flat plate modules dominates the market with 87% share (2010). The efficiency for commercial products in the market (PV modules) typically varies from 15% to 19%, with modules designed to last for at least 25 years. The degradation is guaranteed below 20% after 20 years that is efficiency above 80% of the initial one after 20 years. Further improvement of the efficiency and manufacturing process is expected in the next years leading to cost reduction and extension of the time life, reducing the degradation. Long-term target is also the reduction of the energy payback time of the PV modules below 6 months for Southern Europe solar radiation regime from about 18 months today in this technology.

Fig. 4: *Solar PV plant with crystalline Si modules and constant tilt angle*

Thin film technologies cover the rest 13% of the market (2010) with Cadmium Telluride (CdTe) and thin film silicon (amorphous/microcrystalline silicon, TFSi) mostly and a small share by GIGSS and others (organic). Further penetration of thin film technologies' products in the market is expected in the next years.

The stabilized module efficiency of thin film technologies (TFSi, CdTe, CIGSS) is from about 9% to 13% with good prospects for higher efficiency in the long-term. Thin-film PV has the potential for low-cost because of the small quantity material usage and suitability for fully integrated processing and high throughputs. These technologies have shown long-term stability under outdoor conditions (except for the organics). The energy payback time of thin-film modules is already less than one year in Southern Europe solar radiation environment, and there is potential for further reduction.

There are some advanced PV technologies like the one based on Gallium Arsenide (GaAs) and III-V multi-junction based solar cells with high efficiency exceeding 40%. These high efficiency cells are expensive and can be used with solar concentration devices, such as the concentration ratios below 100 suns (low concentration PV, LCPV) and from 300 up to 1,000 suns (high concentration PV, HCPV). The multi-junction III-V based cells are now the baseline technology for the majority of satellite power systems, leading to synergistic benefits to both space and terrestrial applications. Concentrator module efficiencies have reached 29% and full-scale systems 25% AC operating efficiencies. Multi-junction based solar cells with efficiency exceeding 50% are expected in the next years for efficient use in the concentration technology (CPV).

Fig. 5: *Solar PV concentration technologies (CPV) – Concentrator modules with tracking systems*

The PV manufacturing production capacity has been increased and by the end of 2011 exceeded 40GW/yr in total, with six companies having capacities of above 1 GW/yr where the optimized production sequence and process control has led to lower costs.

Today, two main types of PV installations on the ground are used: the constant tilt angle type with optimum annual output and the tracking system with maximum annual output.

The constant tilt angle type of installation is simple, reliable and less expensive, without any excavation and civil works and environmentally friendly. The annual capacity factor of the PV plant is expected to be of about 17% to 18% for southern Greece. The PV plant with this low figure of capacity factor requires the same capacity for the transmission system with the same capacity factor, which results in high transmission cost. Moreover, the intermittent character of power supply creates some problems in the integration of this large power capacity into the management scheme of the electricity system.

The capacity factor can be improved by using the tracking system. The structure of the tracking system with two axes for the PV modules contributes to an increase of the output by about 30% more electricity. In this case the tracking system must be combined with high efficiency PV modules for better economic results and the capacity factor can be more than 22% (for southern Greece). From an environmental aspect, this type of PV application needs excavation and a concrete structure for the foundation which should be taken into account regarding the environmental impact, including visual disturbances.

Today, the additional power generation by the tracking system (plus 30%) is compensated by the additional cost and maintenance of the tracking system. In the near future a significant decrease of the prices for the PV equipment and the installation costs for plants with constant tilt angle is expected, but for plants with tracking system more efforts are needed for significant cost reduction of the total system.

Concentrated PV (CPV) technology is now in the manufacturing phase, suited rather to medium or large size PV applications than small ones. The CPV power plant market is in the beginning at sites with high Direct Normal Irradiance (DNI), such as the Mediterranean areas. In most cases CPV systems require two-axis sun tracking devices. The trackers account for more than 25% of the complete system cost (2010). Future competitiveness of CPV depends on tracker cost reduction.

So far, practically all trackers are made out of galvanized or powder coated steel. The most prominent version is the Pylon tracker, but also other types like ring trackers or horizontal axis trackers are known. The difficulty is to find a tracker architecture which allows for the required stiffness and at the same time reduces the use of steel to a minimum in order to save material and related cost. The drives must be as robust as possible in order to allow for a 25 year service but should not be over-specified for cost reasons again.

Having in mind the above PV technologies, the type of PV installations and the trends, the type of constant tilt angle PV installation with good prospects is selected in the present assessment study, while today the cost difference among them is negligible. However, the final decision should be taken before the implementation of the project following an assessment of the technological advancements and the cost of the transmission system at the time, on the basis of a detailed design and cost analysis.

4.2.2 Installation and siting studies

The siting study should be the first step towards the installation of the solar PV plants which will make up the Helios project. The main parameter for the selection of the site should be the high availability of solar radiation. Areas of higher solar radiation may be found in the southern part of Greece: in Crete and Rhodes islands and in southern Peloponnesus. Taking into consideration the necessary transmission system to central Europe southern Peloponnesus offer more appropriate sites and these should be investigated.

Excluding agricultural land, the arid land which has no real cost, treeless and pasture land in the slopes of south facing mountains with access to the road network should be selected. The pasture land could be used where raised supporting structures for the PV modules are required in order to enable the use pasture land by goats and sheep. Shading studies are also needed in order to avoid any shade in the installation area during the year from the nearby mountains.

It is estimated that an area of 1 to 2 hectares is needed for 1MW of installed PV capacity (with a constant tilt angle), depending on the technology and the slope of the land. This means that an area of 10,000 to 20,000 hectares in total is needed for 10GW solar PV installed capacity, which can be distributed in the available land areas at different sites. The appropriate sites in the mountain areas offer better conditions for an increased output of the PV modules due to higher solar radiation related with the altitude and the lower temperatures especially in summer.

For each site of a PV installation landscaping and an architectural study is required for the successful integration of the PV plant into the natural environment. The foundation of the supporting structure should be studied and implemented accordingly taking into consideration the type of soil, avoiding any excavation and concrete structures. A complete electromechanical study including cabling, grounding and protections including the substations should be carried out for each PV plant.

4.3 The transmission system and the HVDC technology

4.3.1 The transmission system of the project

The giant PV plant with a total of 10GW installed capacity should be oriented to the export of the produced energy to the electricity markets of central Europe. HVDC (High Voltage Direct Current) technology should be used for this long distance electricity transmission with submarine cables. This solution is considered more realistic than others, e.g. by overhead HVDC lines on the ground crossing a number of countries in the Balkan peninsula up to the central Europe electricity markets.
The transmission system should consist of:

- The high and ultrahigh AC (Alternating Current) voltage overhead lines on the ground connecting all sites of PV plants up to the substations in the west coast of Peloponnesus with connection to the national interconnected transmission system,
- The submarine transmission system by cables from the west Peloponnesus coast to the North Italy coast with the converters in each terminal,
- The ultrahigh AC voltage overhead lines on the ground in North Italy connecting the cables terminal in the coast with the nearest ultrahigh voltage substations.

This transmission system by submarine cables will finally become an electricity highway within the European interconnected system, connecting the Greek system with the Italian system in the north and the strong central European interconnected system. This transmission system would be the first step of a European super-grid for solar energy in the south part of the Continent, in parallel with the super-grid for the offshore wind farms now under development in the north of Europe.

Further studies are needed for the transmission trough existing strong interconnections to the Swiss, the Austrian and German systems. The capacity for each connection to these systems should be a subject for further investigation and study.

This highway transmission system will be used for the smooth operation of the electricity markets in Greece, Italy, Germany, Switzerland Austria and others. The produced electricity by the PV plants and other zero or low CO_2 emissions power generation, such as from the wind farms, hydro and high efficiency power plants by natural gas can be transmitted from Greece to central European markets easily and without congestion. The interconnection of the systems between Crete and Peloponnesus by HVDC submarine cables will contribute towards the utilization of the solar and wind potential of Crete substituting oil consumption for power generation. In addition, this interconnection will facilitate the interconnection of Cyprus to Crete and the access of Cyprus to the European electricity markets by exploiting the solar potential and the natural gas for power generation, instead of using submarine pipelines for the supply the natural gas to Europe.

This highway connection system is considered very important for Greece (and Cyprus) having access directly to the central European electricity markets but also for Italy and of course for the European system. The development and implementation of this system could be scheduled for operation beginning the next decade.

The first part of the transmission system is the overhead high and ultrahigh voltage transmission lines, which will be developed on the ground connecting also the Greek transmission system. The technology for these lines is established and well known with high reliability and accurate cost estimation. The proposed transmission system by submarine cables (mass-impregnated HVDC cables) between Greece and north Italy is the most challenging project with implementation involving state of the art and innovative technologies. From 2001, there is in operation an interconnection line between North-West Greece and South Italy (Arachthos - Galatina) based on HVDC technology with submarine cable of 200km length, 400kV and 500MW capacity.

4.3.2 The HVDC transmission system

The high capacity of the transmission system and the long distance involved lead to the use of the HVDC technology. The HVDC transmission system consist (a) of the submarine cables of high voltage DC and (b) the substations in each terminal which are necessary for the transformation of the current, from AC to DC and from DC to AC.

The HVDC cables are currently the only available solution for submarine long distance electricity transmission. The thermal losses in long distances HVDC lines are lower than in AC lines. Moreover, HVDC links connect areas without synchronization of the systems and contribute in facing dynamic security problems and disturbances of the connecting networks.

<u>Fig. 6</u>: *The proposed interconnection of south Greece to north Italy by submarine cables based on HVDC technology and then to the electricity markets of the central European countries - Interconnection of Crete to Southern Peloponnesus*

The HVDC links have the advantage of connecting point-to-point isolated power plants with major load centers. Such transmission systems have been built in order to connect large hydro power plants to areas of high electricity demand. Some examples are the 820 km HVDC line between Itaipu and Sao Paulo in Brazil, the 1100 km HVDC line connecting James Bay with the consumption centers in Canada and the U.S, the 890 km HVDC line between Three Gorges and Changzhou, in China. The project Fenxia-Fulong in China is under completion with 2,071km length, voltage at ±800kV and of 6,400MW capacity, while other projects with longer distances are under planning. In this way, bulk power can be transmitted directly where it is mostly needed with less power losses and without overloading other lines or substations.

The operating voltage level could be ± 600kV or ±800kV for the long distance overhead lines to minimize thermal losses.

Applications of HVDC by submarine cables have usual a voltage level of ±500kV, while voltage of ±600 is effective today and probably ±800kV in the future. The first sub-sea electricity link between Scotland and England of 261 miles length and 2,200MW capacity will use a DC cable with voltage level of ±600kV. It is planned to be fully operational by 2016.

Some existing or planned submarine HVDC links are presented in Table 7. More information and data for existing and planned applications can be found in the bibliography. The longest submarine cable to date is that interconnecting Norway with the Netherlands (580km since 2008). The deepest submarine cable in the world is currently that connecting Sardinia with mainland Italy (at 1,600m sea depth, 2010). A submarine cable with 260km length interconnects the UK with the Netherlands, which is in operation since April 2011. The project connecting Norway with Germany with 570km length is still in the planning phase, with estimated project completion date in 2015.

Table 7: *Some existing submarine HVDC links in operation or planned in Europe*

Connecting HVDC links	Length (km)	Voltage (kV)	Capacity (MW)
Norway-Netherland	580	±450	700
Sardinia- mainland Italy	435	±500	1,000
UK-Netherland	260	±450	1,000
Norway-Germany (planned for 2015)	570	450-500	1,400
England Scotland (planned for 2016)	420	±600	2,200

Some indicative cost figures related with the capacity, the length, the sea depth etc, for the above completed interconnections, which are already in operation, include the following: Norway-Netherland €600 million, Sardinia-mainland Italy €750 million, UK-Netherland €600 million. The planned interconnection Scotland-England has an estimated cost of about 1.2 billion€.

For the present project the distance from west Peloponnesus to North Italy is about 1,100km and the sea depth is manageable with the existing technology. The capacity should be 10GW and the voltage level of the HVDC could be in the level ±600kV, effective today. The availability of the HVDC links is high exceeding 99% and the life expectancy is more than 40 years. The efficiency of the proposed transmission system is high and the total losses are estimated at about 4%.

In the present assessment study, an HVDC submarine cable HVDC from south Greece to North Italy is proposed as a more realistic solution. Some other alternatives could be by overhead HVDC lines through the Balkan countries or by submarine cable to south Italy and then by overhead HVDC from the south to north Italy, taking into account that the submarine cable currently is two to four times more expensive than overhead lines. However, the environmental issues and the social or the NIMBY problems connected with the overhead lines on the ground, through five countries in the Balkan peninsula or through Italy, should be taken into serious consideration. During the study the necessary investigations for alternative solutions should be carried out, considering also the operation, the reliability and the availability aspects, the maintenance problems and costs and taking into consideration the expected improvements in technology and cost reduction of HVDC at that time.

The connection of Crete to southern Peloponnesus, in parallel to this project, in order to increase the penetration of RES into the system will facilitate the further exploitation of solar and wind energy for export, besides other benefits. Moreover, this interconnection will facilitate the interconnection of Cyprus to Crete and then to the European interconnected system. The access of Cyprus to the European electricity markets is of high importance for both sides and can contribute to the export of electricity based on solar PV and natural gas, instead of natural gas exports to the European markets, which is preferable to the installation of submarine gas pipeline. The interconnection of four neighboring to Greece countries including the large electricity system of Turkey to the European interconnected system through Greece, as an alternative way in the region, should be also taken into consideration.
Thus, a well-designed transmission system with state of the art technical features and for a long-term time horizon will provide high flexibility in the operation of the systems and the markets avoiding any congestion. In this case better exploitation of the transmission system and high reliability in the power supply can be achieved by increasing the penetration of RES into the electricity sector.

4.4 Further development of the HVDC technology and innovations

Further development is needed and additional experience might be necessary for the multi-terminal technology to connect several HVDC lines in one node. No significant barriers are anticipated from a technical point of view, while good efforts are being carried out for further development of HVDC switchgears, protection and control systems. Therefore, investigation should be carried out for the route of the transmission system in the proposed project and the connection points for this high capacity.

Depending on the maturity of the technology, two connection points of the Greek transmission system, in west Peloponnesus coast and in the north-west Greece coast, to the Italian transmission system could be investigated for total or part of the capacity. Within the same concept two connection points of the Italian transmission system, in the south and in the north of the east coast with reasonable capacity, should be also investigated for a possible operation in Italy from the south to the north or reverse, depending of the maturity of the HVDC technology. This concept aims at improving reliability and flexibility in the operation of the systems and the electricity markets.

An important parameter which should be taken into account is the number of hours that the HVDC transmission line can operate in full capacity in one or both directions every day. In order to change the power flow direction for the Current Source Converter technology (HVDC-CSC), the voltage polarity must be inverted with impacts to the available transmission capacity and operation time. This limitation does not exist in the Voltage Source Converter technology (HVDC-VSC, near to large commercial applications) and for this reason the HVDC-VSC technology is considered more suitable for an HVDC grid, such as the one which is proposed for use in this project.

This advanced technology offers high flexibility in the operation of the network in case of change the energy flow and the direction to correspond smoothly the demand and to intermittent character of power generation by wind and solar as well. This innovation is significantly important in the case of interconnection of the islands with high potential of solar and wind without storage.

The HVDC technology, which was developed and used worldwide in the past mainly for the case of large hydro to one way supply, must be adapted now to RES features. Taking into account the large penetration of RES during the next decades and the life time of this technology, the design/development of the transmission systems should be able to cover the demands of 2040 and 2050, considering the intermittent character of wind and solar energy. This technology with innovations will lead to future transmission networks with high flexibility, contributing to high RES penetration into the electricity sector and the operation of systems and electricity markets.

Future electricity systems must be characterized from flexibility in power generation, in transmission and in consumption and storage facilities as well. Moreover, further development of control strategies and systems is absolutely necessary for future needs in energy flow control and improved management of the system. In addition, new tools and regulations must be developed for the operation of the electricity markets.

Thus, this project of a European scale, connecting south-east Europe to central Europe is a challenging project for the European industry to integrate innovations, opening the way for future large interconnections.

4.5 The participation of solar PV power generation in the electricity market

Currently, the feed-in tariff scheme is dominated by solar PV power generation supplied to the grid and for other RES as well. Technology development and the expansion of the market will inevitably lead the feed-in tariffs to decreasing trends. Grid parity for solar PV power generation is expected over the next few years for the southern European countries, and by the end of this decade the participation of solar PV power generation in the electricity market should be possible. Therefore, the output of the proposed 10GW solar PV plant should be based on market forces and prevailing prices rather than on political decisions related to artificially high feed-in tariff schemes.

For this reason various tools should be developed and introduced, such as solar PV power generation forecasting models and management tools, for better exploitation of the produced energy. Moreover, new regulations adapted to new RES market features of RES technologies should be introduced, providing also ancillary services to the network.

Through the interconnections, there is flexibility for the output of the PV plants to participate mainly in the Greek, Italian and German markets and in some others as well. Regarding the Greek and Italian markets, which have a significant capacity of hydropower and large water storage facilities, the daily peak, considering the time zone also, will be covered by the PV plants while the hydropower operation should be withheld for the evening peak hours.

Besides the PV power generation transmission with a capacity factor of about 18%, the exploitation of the HVDC transmission system should be extended, e.g. during the night hours or in the winter period by introducing other sources, such as wind energy which may act as a complementary source to solar energy, or power generation by natural gas. These additional sources can be used to improve the capacity factor and the economics of the transmission system. The interconnections combined with hydro can contribute to reduce the storage capacity and thus, alleviate the bulk storage of electricity.

In the future, the high penetration of RES into the electricity networks and because of their intermittent nature, mainly in the case of wind and solar power, higher volatility of electricity prices should be expected, from very high to negative prices. However, extensive interconnections between the networks and the markets can substantially mitigate such extreme phenomena. Moreover, taking into account the time zones and the differences in climatic conditions between north and south Europe, the interconnections can contribute towards the smoothing of wind and solar electricity supply and electricity demand, reducing storage needs. Thus, the necessity to move to a more interconnected power grid between South and North should be emphasized for Europe. Greece with its extensive power generation capacity and with several interconnections in the north, east and west can participate in the regional market within the Energy Community. In the South, through the proposed 10GW transmission system capacity Greece shall be able to participate directly in the markets of central Europe, by-passing the weak transmission system of the Balkan countries.

Thus, Greece shall be able to exploit its RES potential in the best possible way focusing on exports. Because the variations of the electricity prices will eventually be minimized the consumer shall be able to enjoy a relatively constant and, in average, lower prices.

4.6 The economic and societal aspects

Detailed feasibility studies must be carried out on a technical, economic and societal level in order to substantiate the benefits and the challenges that need to be addressed. The power generation cost from solar PV plants and probably by wind is the main economic parameter to be considered followed by the transmission cost. Taking into account the high solar radiation levels in southern Greece and the benefits from the economy of scale of such a large PV plant, the power generation cost is estimated at significantly lower level, compared to the relevant costs of the countries in central Europe. In the same way, selected sites of high wind potential could lead to significantly competitive power generation costs by wind and solar in Greece compared to central Europe.

The transmission cost depends mainly upon the investment cost for the transmission system and the capacity factor in the exploitation of the system. The annual capacity factor for solar PV is estimated between 18% and 23% (in the south by constant tilt angle and for tracking systems). An improvement can be achieved with the inclusion of power generation by wind with a capacity factor of about 40%, and in some cases of power generation by natural gas. Besides the contribution of the hydro in the system management, the battery storage facilities (and the available pump storage) combined with the solar PV power generation is capable of increasing substantially the capacity factor of the output. In this case better results in the exploitation of the transmission system and the operation of the electricity system should be expected, achieving better prices in the electricity market.

Besides the submarine HVDC cables, the relevant charges for the overhead lines on the ground in the terminals, both in Greece and Italy should also be considered. This route for the transmission line by submarine cables has some advantages, although it is more expensive than totally by overhead HVDC lines over four or five Balkan countries. Therefore, the implementation is more realistic by sea, while the reliability in the operation is high with very low O&M cost. In the other solution, i.e. by overhead lines over the Balkan peninsula, the transmission costs with the relevant charges in five countries should be taken into account. Considering some technical and economic parameters it seems that the proposed transmission system is realistic and can be technically feasible and economically competitive.

From the societal aspect, a number of new jobs is expected to be created during the implementation and operation of the wind and solar power plants producing clean electricity, without serious impacts to the environment. Special design in the PV supporting structures must be introduced especially in the case of use of pasture land in order to achieve both uses. The design and implementation of the overhead high voltage lines on the ground in Greece and Italy may meet some difficulties and the optimum solution should be investigated. This interconnection moves towards an ever increasing participation of RES in the electricity production with environmental benefits, reducing the CO_2 emissions.

The anticipated high capacity of the interconnection between Greece and central Europe opens the way for large scale exploitation of solar and wind energy in Greece. This is a huge project on a European scale, beyond national dimensions and should be developed as a joint project with the participation mainly of European companies and others worldwide too. Currently, a huge solar PV market and applications exists in Europe but the huge manufacturing capacity is to be found in the Asian countries (mainly in China, Taiwan and South Korea).

In order to increase the benefits for Greece and also for the project, the development of indigenous manufacturing activities concerning equipment for solar and wind applications should be investigated. In addition to the equipment needed for the “Helios” project, the local and regional markets regarding solar PV and wind applications should be investigated for the local manufacturing of the necessary equipment. The best technologies in solar PV and wind should be selected for the development of local manufacturing activities for the needs of the proposed project and for the regional market.

Concerning the production of solar PV modules there are currently six companies worldwide with more than 1GW annual production capacity. For the 10GW project a few large PV companies must work for several years for the production of the PV modules for the project. As an example, a new local facility with 2GW annual capacity and competitive prices to operate for 5 to 10 years minimum is needed for covering the needs of the project and those of the local and regional markets.

The investment cost for the proposed transmission system is heavily dependent on the voltage level. For example, besides the reduced thermal losses, from the investment cost point of view the voltage level ±600kV is better than ±500kV, while ±800kV for long distances is much better with regard to the cost of the submarine cables and the terminal converters. A detailed study for the introduction of innovative concepts, such as the multi-terminal technology or the Voltage Source Converter technology (HVDC-VSC), which is expected soon for large capacities, will determine the technical and operational characteristics and the relevant cost as well. Due to the high capacity of the transmission system and its long length the specific cost per km and per GW is expected to be low having in mind the current figures of investments in other projects. The cost estimations for large HVDC submarine transmission systems vary regarding the cost of the cables and the cost of the converters. Cost figures for three large interconnections HVDC by submarine cables in Europe already in operation, have been presented above in chapter 4.3.2. A rough estimation for the specific costs regarding the capacity and the voltage is presented here based on the completed projects already in operation, some planned projects and data to be found in the bibliography.

An indicative specific cost for the submarine cable (±600kV, 3GW capacity) is estimated between 1.1 to 1.7 million € per km both for the supply of the cables and the installation. For the converters it is estimated between 250 to 350 million € for each terminal. The rough estimation for the relevant specific cost of the overhead lines (HVDC) could be in the range of 0.2 to 0.6 million € per km, considering the high figures due to social problems. It should be noticed that all innovative technologies should be integrated in the implementation of the project, while lower prices should be expected for this technology in the years ahead.

A rough estimation of the transmission cost for the proposed HVDC transmission system by submarine cable based on the current operation experience should be of the order of 0.01 to 0.02c€/kWh. An increased capacity factor (above 18%) is considered through the contribution of wind energy, having in mind the good wind regime in specific areas in Greece during summer and winter months with competitive power generation costs compared to the North Sea offshore wind farms. In addition, the losses in the transmission system and the charges for transmission by the ground-based overhead lines to reach the relevant markets should be taken into account.

The decreasing cost of RES power generation related with the RES potential in Greece by the end of this decade and the significant anticipated increase of the electricity cost from fossil fuels makes realistic the idea of exporting RES electricity. The competitive RES electricity from Greece can indeed be exported to the central European markets with economic and social benefits in the long-term.

However, regarding the solar PV electricity, the total transmission cost of the electricity from Greece to central European electricity markets plus the losses must be lower than the difference of solar PV power generation cost in Greece and in central Europe, due to the difference in solar radiation. Thus, solar PV power generation cost in Greece below a certain limit (e.g. <6c€/kWh) would be critical for the economic viability of the transmission system and in general for the realization of this idea for solar PV power generation export.

Although the technological and economical feasibility seems to be attractive, the decision for implementation of this joint project depends rather on wider social and political support.

4.7 The next steps – The implementation time framework

A prefeasibility study with further investigation of the relevant technological, economical and societal parameters, as mentioned above and a sensitivity analysis for some crucial parameters should be carried out. The study must focus on the exportation mainly of solar PV power generation and possibly of wind and natural gas power generation to central European electricity markets. The study and the results should be based on the latest technological developments and the operation of competitive electricity markets. This joint project which focuses on the future RES domination in the power generation sector has nothing to do with the concept of "Project Helios".

Following the results of the feasibility study, which will confirm the idea of RES exports as it is widely expected, a series of important actions must be planned by the Ministry towards the implementation, mainly along two directions.

Political support of course is needed by Italy and other European countries, as well as from the high level personalities in the EU and the European Commission. Support is also needed from the ENTSO-e to include the transmission system of this project to the European networks. Another action must be an open call for investors providing at the same time some incentives, in order to establish a joint venture for the project. The European industry will be is asked to take part in what is clearly a most challenging pan European plan. The project should be implemented and operated by the private sector with political support from the EU and specifically by the interested countries.

Thus, an initiative based on the above analysis must be carefully elaborated and launched by the Greek government with clearly defined strategic goals for power systems interconnecting and exporting of solar PV power and RES electricity in general to central Europe.

The siting studies, mainly for solar PV plants, must be carried out and the necessary land must be provided by the state with nominal price of rent as incentive. Some other incentives could be tax credits, over a specific time period, and maybe some kind of subsidy for manufacturing activities. Any intention for business activities to be undertaken by the state must be avoided at all costs and all efforts should be concentrated in facilitating the realization of the project, taking into account the multiple benefits that the project will bring to the national economy for the long-term.

In parallel, some studies must be carried by the Hellenic TSO, regarding the benefits for the Greek electricity system and the market and through better exploitation of the interconnections. Moreover, the interconnection of Crete to Peloponnesus must be scheduled and implemented within this project or separately in advance, considering the substantial benefits of the interconnection in the long-term and the optimum exploitation of the RES potential. In addition, this interconnection will facilitate the interconnection of Cyprus to Crete and then to the European interconnected electricity system.

The most difficult part of the project is the transmission system with its demanding timetable which is needed for the design-development and its implementation. Moreover, new regulations for the operation of the electricity market with large RES penetration by exploiting the electricity transmission capacity should be adopted. Thus, the commissioning of the project should be scheduled at the end of this decade, when the power generation cost by RES would be lower and competitive in the market. Due to the modular nature of PV equipment the project can be realized in several phases during the next years up to 2020 so as to gain experience and further improve its design-implementation.

5. Conclusions

The systematic simplification of the bloated bureaucratic procedures involved in the local licensing of RES applications is of paramount importance and will help reduce the investment costs and consequently it could contribute to the reduction of the current feed-in tariff figures with significant benefits to the consumers and the economy. The existing tariff scheme with high figures and lack of transparency is a very crucial problem with serious impact to the economy and the consumers.

The deregulation of the electricity market in Greece has been seriously delayed and currently there are some efforts in removing the existing barriers. However, the domination of the high RES tariffs for long period based purely on political decisions in conjunction with the ambitious target for 2020 will jeopardize the electricity market, maintaining rather a regulated electricity market.

The restructuring of the legal framework for RES and the introduction of a rational feed-in tariff scheme based on the best European practices is urgent and absolutely necessary.

As the project has been presented today by the Greek government all crucial business parameters for "Project Helios" are in the wrong direction and inconsistent with market rules. From the technical aspect the transmission of such huge solar PV power generation capacity to central Europe needs the design and installation of a high capacity transmission system. The additional budget and the time horizon for the implementation of the transmission system are factors which are totally missing from Greek government thinking. Thus, there are a number of uncertainties which seriously undermine the prospects for the realization of the project. Consequently, any government expectations for a sizeable contribution of "Project Helios" to Greek debt reduction are totally unfounded.

However, a new "Helios" project based on advanced and innovative technologies and on market forces can be developed with a positive impact to the economy and with mutual social and economic benefits for both sides, the producers and the consumers, over the long-term.

There are good prospects for the development of solar PV technologies and their competitiveness against fossil fuel power generation. Moreover, grid parity is expected during the next years in southern European countries and PV power generation cost will be competitive so as to partake in the competitive electricity markets by 2020. Generally, the idea for the export of solar PV power and probably wind power from Greece to the central European countries is ambitious but seems to be realistic over the next few years.

The interconnection of southern Greece to north Italy, in order to reach the electricity markets of central European countries is of high importance to Greece and Italy too. It is also considered very useful for the central European electricity markets and the European interconnected transmission system. In addition, this interconnection can be combined with the interconnection of Crete to Peloponnesus and Cyprus to Crete so as to multiply the benefits. In general, it will be an interconnection of the south-east Europe to central Europe.

The technological and economic feasibility seems to be very attractive with high expectations. This joint venture project could be scheduled for implementation in the mid-term when the maturity of the project and the technologies will be achieved, in conjunction with the RES-e competitiveness. Moreover, this is considered as a challenging project for the European industry towards the future electricity grids worldwide.

Therefore, coordinated actions must be undertaken by Greece both at a political level, in order to ensure support, and also on business level by attracting investors and providing some incentives, on the basis of a prefeasibility study for this joint venture project. Additional benefits are expected from possible manufacturing activities for the equipment of RES power plants.

Due to the technological and financial demands commissioning the complete project should be scheduled for 2020. The expected benefits from such huge and highly important project with favourable impact to the Greek electricity system and the economy must be the driving force for the Ministry to be motivated to undertake the necessary actions. Thus, an initiative for a new “Helios” project based on technological and business perspectives in the context of a competitive electricity market, must be elaborated carefully and re-launched by the Greek government with clearly defined strategic goals for power systems interconnecting and exporting of solar PV power generation to central Europe.

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About the Authors, short CVs

John Chadjivassiliadis

Dipl. Mechanical and Electrical Engineer of the NTUA (1960). Expert in the development of the renewable energy sources and sustainable power systems. Worked for the Public Power Corporation (1962-1990) in the department of power generation, director of power plants, and project manager in large power projects. From the mid-1970s John was in charge of the development of wind and solar energy projects for power generation with the successful Windpark of Kythnos, the first in Europe (1982) and the biggest hybrid by wind and solar PV.
Since 1990, he is consultant engineer, especially in the renewable energy sources, energy efficiency and sustainable development. For many years he served as an expert in evaluating research proposals and programs, coordinator and technical assistant of large research projects for RES integration into the networks within the European Commission Research Programmes. Founding Member of the European Wind Energy Association (EWEA, 1982) and member of national and EU missions for international cooperation in scientific research and technology. He is Founding Member and General Secretary of IENE, National Representative in the Mirror Group of the European PV Technology Platform, Member of the Scientific Committee of the Hellenic Association of Mechanical and Electrical Engineers, Major in Reserve of the Hellenic Army in the Technical Corp.
John is the recipient of the “Prize Aeolus” Award, for his contribution in wind energy development, by the Hellenic Wind Energy Association/Member of EWEA (2009) and of the “2010 PES Chapter Outstanding Engineer” Award, for his contribution in renewable energy research and development, by the IEEE Power & Energy Society, PES Greece Chapter.

Costis Stambolis

He studied Physics and Architecture at the University of London and North East London Polytechnic respectively and holds a Graduate Diploma in Architecture and Energy Studies (AA Dip. Grad) from the Architectural Association in London (1983) and a professional practice license from the Technical Chamber of Greece (TEE)(1987). He has carried out numerous studies and projects on Renewable Energy Sources in developing countries specializing on solar energy applications for buildings. He has consulted widely on solar building applications in Greece both for private and institutional clients. He has worked as a consultant on solar energy, natural gas, oil markets, and energy security issues for large multinational companies and international organizations. He has lectured widely on energy issues in Greece, the UK, and USA. He has organized several national, regional and international conferences, seminars and workshops. He has pursued a parallel career as a specialized technical writer. He has edited several books, conference proceedings and has published many specialized papers and studies on energy policy, solar energy, RES and energy markets. “The Greek Energy Directory” (1984), “The Greek Energy Market” (2001) and the “S.E. Europe Energy Outlook 2011”, all edited by Costis Stambolis are considered basic references on energy policy in Greece and SE Europe. Since 2001 he supervises and edits daily Greece’s foremost energy site www.energia.gr . He is a founding member of the Institute of Energy for South East Europe (IENE), where he was elected twice as its Chairman (2003, 2005). He is currently IENE’s Deputy Chairman and Executive Director. He is a member of the Institute of Energy (UK), The Technical Chamber of Greece (TEE), The Foreign Press Association (Greece) at the Chartered Institute of Journalists (UK).