The current state of the PV markets and PV technologies

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Abstract: - The Photovoltaic (PV) sector is one of the fastest developing industries at this moment, as an indication it is noted that the PV cell production increase for 2004 was 60% compared to 2003. For the last five years, the production of PV cells has increased regularly, at an annual average rate of 40%. Over the last ten years the manufacturing cost has decreased and the efficiency has improved reaching for the most advanced laboratory cells of crystalline Silicon, to more than 24%, while commercial PV modules are made of cells with efficiency in the range from 11 to 18%.

Key-Words: **-** Photovoltaic, market, PV technology, Greece

1 Introduction

The Photovoltaic (PV) sector is one of the fastest developing industries at this moment, as an indication it is noted that the PV production increase for 2004 was 60% more than 2003. For the last ten years, the production of PV cells has increased regularly, at an annual average rate of 40%. This growth is not only led by progress in materials and the technology of manufacturing but mainly by the market introduction support programs for PV systems in several countries, particularly by the Germany, Japan and USA. These programs contribute in the increase of demand for PV systems with a corresponding investment in mass production manufacturing lines that will lead to less expensive products because of the economy of scale that they will achieve. Currently, the manufacturing of solar cells is based on crystalline Silicon technologies which account for 93% of the world production of PV cells. The PV systems constitute in the long run one of the more important renewable energy technologies for the production of electric energy, because they have the possibility of integration in all cases (autonomous systems, central systems, PV integrated in buildings-BIPV) producing energy that will be channelled into the grids. More important advantages constitute: the possibility of designing aesthetic solutions that do not burden particularly the environment and the modularity of the PV systems. Distributed generation energy units even, when they do not constitute structural element of buildings offer also the advantage of short time of installation and operation. The PV systems are reliable and friendly to the environment. The cell efficiency has improved reaching for the most advanced laboratory cells of crystalline Silicon, to more than 24%, while commercial PV modules are made of cells with efficiency in the range from 11 to 18%.

The large introduction of PV of systems may replace or postpone the extension of conventional central stations of electricity production having a positive impact on the environment. The PV system electric power is of particular value when it coincides with the peak demand, as during the summer afternoon peak due to the use of air conditioning units. Moreover, PV systems contribute to the improvement in power quality, the reduction of electricity transport losses by producing at the point of consumption and the increase of reliability of the electric power system

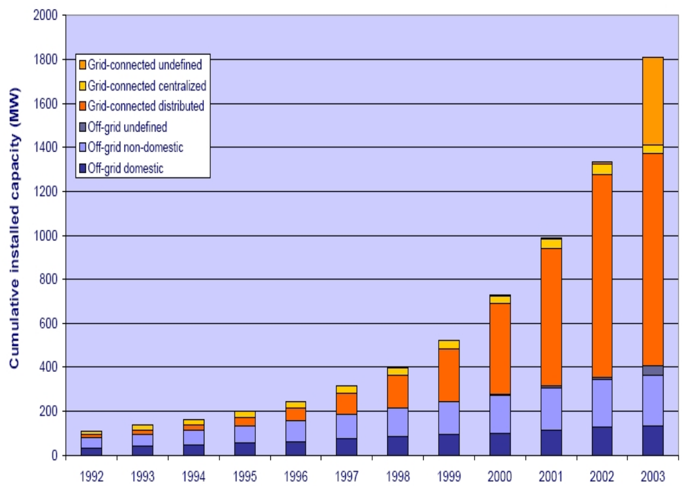

Figure 1: Cumulative installed PV power by application area in the IEA countries [1].

2 Worldwide PV Markets

The applications of PV systems have risen from a world accumulated installed capacity of 375 MWp in 1995 to roughly 3900 MWp in 2004. The total installed capacity of PV up to 2010 is expected to reach 10000 MWp. Taking into consideration the explosive trend of the German market, the European installed capacity forecast for 2010 amounts to 4500 MWp, versus the E.U White paper goal of 3000 MWp.

The largest PV system market in Europe, which is Germany has installed in 2003 130 MWp and it was the second largest market in world after Japan with 220 MWp installed in 2003. The first counts of 2004 have shown that Japan is no longer the largest market as, according to Photon International in 2004 there were between 593 and 673 MWp of PV installed in Germany or 363 MWp according to the Association of German Solar Sector Industrialists (BSI), in both cases surpassing Japan which had installations amounting to roughly 300 MWp. In figure 1, the cumulative installed PV power by application area in the IEA countries, which accounts for about 70 to 80% of the world PV installations are presented from the year 1992 through 2003 [1].

Over the past 10 years, the PV support programs in Germany and Japan, either subsidized the initial investment cost of the systems and/or the production of electric energy. These programs have contributed to a large installed PV capacity. As it is noted in Figure 2, the improved feed-in tariff in Germany has better results than a previous program that allowed partly subsidizing the initial investment cost and the solar energy produced [2]. Subsidizing the solar electric energy produced has other benefits as well. It is easily managed through the existing billing scheme and the cost of the solar kWh is spread among all the electricity users in Germany. The PV system owner is also interested to keep his system operating optimally for as long as possible in order to produce electricity and gain money. Usually the residential PV programs depending on the local solar resource are supported in such a way as to be able to recover the investment in 8 to 10 years. The contract for energy buy back with the electric system operator is usually more than 20 years long. Germany and Japan with their leading attitude have given the example, how the PV technology can be promoted and applied effectively while their national industries profit developing innovative and reliable products that are also exported in other markets.

According to Michael Rogol, the author of the financial study on the world photovoltaic market that was published in 2004 by the CLSA (Crédit Lyonnais Securities Asia), the PV industry will continue to grow at the same rate with a turnover for solar sector companies that could reach between 30 and 40 billion dollars (between 22.5 and 30 billion euros) in 2010. Assuming that the mean price of a PV system is 7 Euro/Wp, and taking that the installed capacity for 2004 was roughly 1250 MWp, then the PV system sector represents worldwide a total turnover roughly of 8 Billions Euro. This amount is comparable to the corresponding turnover of the wind energy sector worldwide, even though there is a large difference in yearly installed capacity due to the average cost per Watt difference between the two technologies (6.3 to 1). Worldwide, the wind power industry installed 7,976 megawatts (MW) in 2004, an increase in total installed generating capacity of 20%, according to figures released by the Global Wind Energy Council - GWEC. While cumulative world wind power capacity has grown to 47,317MW.

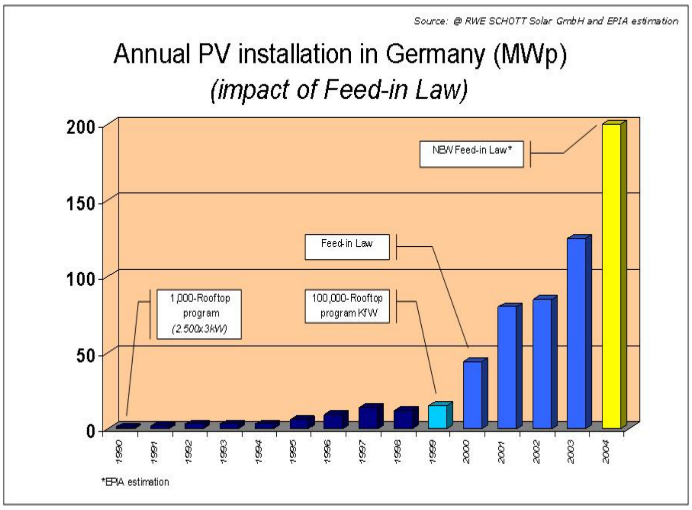

Figure 2: Annual PV installation trend in Germany [2]

3 The Greek PV Market

In Greece, there is no support scheme for residential PV installations and therefore the market penetration is low. The installed PV systems in Greece are mainly privately owned autonomous systems in remote location where there is no grid. The grid connected market, besides a few demonstration projects, is still not existent. Although there is legal framework for the RES market since 1994 the bureaucracy, the involvement of many public services in order to receive a large number of licences and the lack of concrete regulations for the market players have hampered the larger introduction of PV systems. During the past few months the government with the support of all the concerned organisations is working on a new RES law that will simplify licensing, and propose new support measures for RES including PV installations in Greece.

The annual installed capacity of Photovoltaic systems in Greece, if the demonstration programs and research projects are excluded, does not exceed 150 to 200 kWp.

Figure 3 presents the installed capacity of PV in Greece according to the estimates of CRES [3].

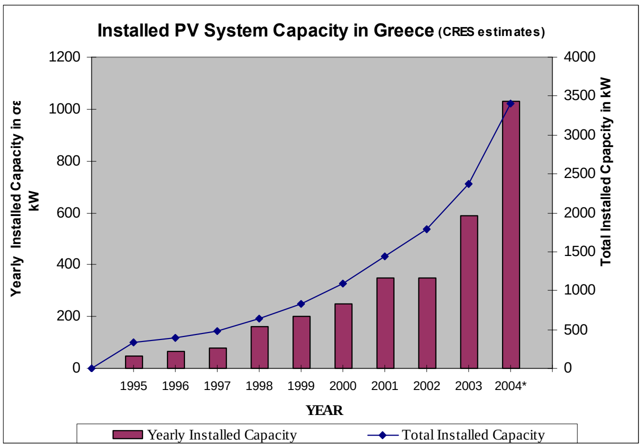

Figure 3: Installed cumulative and annual PV capacity in Greece between 1995 and 2004 [3].

An important increase in capacity is observed in the last two years as a large number of autonomous PV hybrid systems were installed in remote locations supplying base transmission stations of mobile telephony companies supported by the 3rd Community Operational Framework Programme, "Competitiveness" (E.P.An). During the last 2 years roughly 160 such systems were installed by the mobile phone companies, with a total PV capacity of 1.2 MWp, while 80 more systems with a capacity of about 1 MWp remain to be installed. Until recently, the existing base stations were electrified by diesel-generators as they were installed in remote non-electrified locations. The objective of the particular action was the important reduction of the diesel-generator operation time so that important saving of fuel is achieved, with the corresponding environmental benefit. At the same time, the PV-hybrid system offers higher flexibility and reliability. Furthermore, there is a reduction of technical crew visits because the need for frequent fuel replenishment is reduced as the fuel consumption and the corresponding necessity for maintenance are lower.

In the years between 1997 and 2001, three successive calls for proposals of the 2nd Community Operational Framework Programme “Energy” (KPS-2) were announced, the interest for the first two calls was small due to the low investment capital subsidy offered, varied with the geographical region of application, ranging between 40 and 55%. For the 3rd call a subsidy of 70% in the initial investment cost was announced concerning investments of enterprises in PV systems in the island of Crete. The interest was relatively strong and 45 applications for projects were submitted. After the proposal evaluation, 25 projects were approved for a total installed capacity of 2 MWp and a total budget roughly 15.26 million Euro. Finally, only 10 systems were materialised for a total installed capacity of 770 kWp. All, except one small 10kWp system, were connected to the island grid. The projects that were abandoned faced problems in the process of receiving the required licences, while in certain cases the investors considered that the investment was not viable any more, as after the budget was drawn the PV module prices increased by 20-25% because the Drachma was gradually devaluated against the US Dollar by the same amount.

An important application in Greece since 25 years has been the electrification by PV systems of lighthouses, beacons and buoys located in islands, capes and in port entrances. The Service of Lighthouses of the Martial Navy responsible for the safe sea navigation in Greece has installed more than 1000 small PV systems of a total capacity more than 70 kWp and practically all remote lighthouses and beacons are being supplied by PV systems.

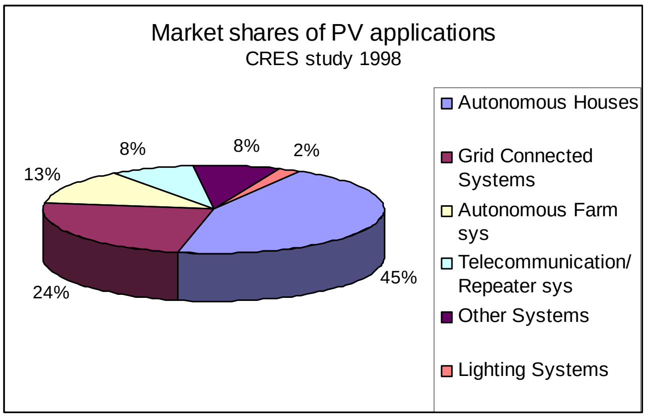

Figure 4: Allocation of the PV market segments in Greece, as reported by the CRES study in 1998 [4].

In figures 4 and 5, the basic segments of the Greek PV market and their shares in the market are presented for the year 1998 [4], when a study was carried out by CRES in the framework of the THERMIE B project titled: “PV markets on the Mediterranean, Assessment of potential barriers. Action plan for development”, (STR-0938-96-GR), The data for 2004 represents the calculated estimates made by CRES.

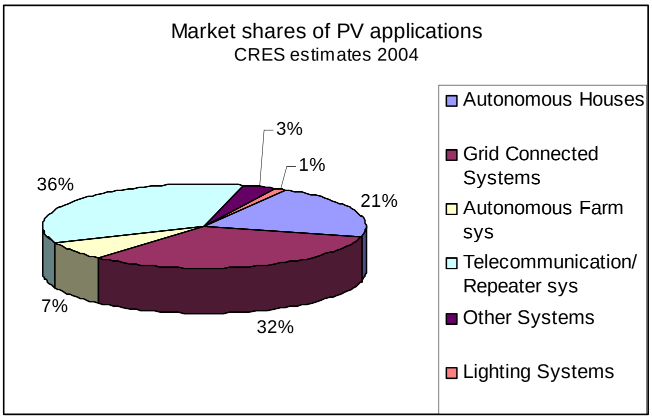

Figure 5: Allocation of the PV market segments in Greece, as estimated by CRES for 2004.

A first observation reveals a large increase in the percentage of telecommunication systems from 8 to 36%, as reported by the recent installations which are supported by Operational Programme for Competitiveness. An increase is also seen in grid connected systems, from 24 to 32% due to the 3rd call of the 2nd Community Operational Framework Programme "Energy", as 760 kWp PV were connected to the grid of the island Crete.

4 Effective PV Dissemination Programmes

The dissemination programmes as well as the pressure from the White Paper goal for renewable energy production by all EU members, the Kyoto protocol emissions reduction obligations and the need to diversify our energy production mix, in combination with electricity market liberalisation has caught the attention of entrepreneurs and a few efforts are underway to establish photovoltaic module production in Greece. Nevertheless, the markets that are created with political decisions and are subsidised cannot be maintained for ever. The goal of the programmes are to support the large introduction of the PV systems and in turn the mass production and the technology improvements and breakthroughs will eventually bring the cost of solar photovoltaic electricity to be comparable to the bulk power production. As it can be seen in figure 6 [5], the current PV solar electricity production cost for southern European countries (1800 Hour/annum insolation) is 0,30 Euro/kWh. In the following years, it is estimated that the PV solar electricity cost will first start competing, around 2010, with the peak power production units of the utilities (red area) and later as the PV module cost is reduced significantly, by the year 2030, with the bulk power production cost of the utilities (blue area).

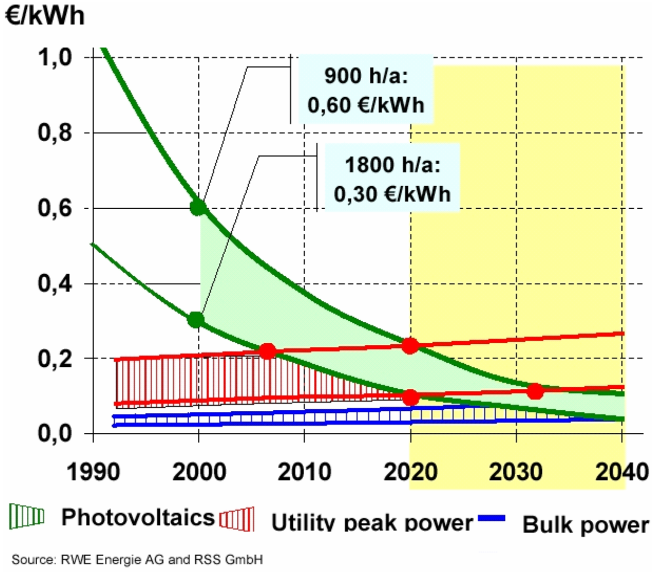

Figure 6: The estimated evolution of solar PV electricity production compared to conventional power supply for two different locations, Northern Europe (900 hours/annum) and Southern Europe (1800 hours/annum) [5].

Figure 7: An office building in Maroussi, Greece with a 11kWp BIPV system.

The BIPV systems, see Figure 7, will be the first grid-connected economical viable application of PV in the developed world without any financial support as it is noticed from Figure 6.
A new law for the promotion of electricity producing RES systems is under preparation in Greece. The law foresees to subsidize the PV electricity produced by roughly 40-50 € cent/kWh. Such a support scheme would help the larger introduction of PV systems in Greece. The support measures should make sure that individual house owners would have the benefit of installing PV systems on their roofs given with a simple operation framework.

5 PV cell technology and industry

The most wide spread PV cell technology is the crystalline Silicon (Si), composed of cells of mono-crystalline Si, poly-Si, edge defined and ribbon Silicon cells. Roughly 93,8% of the world PV cell production in 2003 was made of crystalline Si. The rest of the market is covered by thin film PV technologies, amorphous silicon (a-Si), Cadmium Teluride (CdTe) and the Copper Indium Gallium Diselenide (CIGS). Figure 8, presents the world production share of various PV cell technologies [6].
Even though, the crystalline Silicon technology has a high degree of maturity further improvements in cell efficiency and in production technology are expected. The large companies that deal with PV module production, while they expand their capacity in crystalline Silicon, they have already invested in at least one thin film technology. Among thin films the more mature technology is by far the amorphous Silicon, which has been available commercially for 15 years. The progress with regard to the efficiency of amorphous Silicon cells is stagnant, but experience has been acquired in manufacturing PV generators of large surface and controlled optical transmissivity suitable for building integration.
Although there are some material toxicity concerns about Cd in CdTe, CdTe and CIGS thin film technologies are now in the first steps of commercialization with high expectations for success and continuing improvements in efficiency, production cost and reliability.
As far as manufacturing processes are concerned, there is still a lot of room for improvement from a technical and commercial viewpoint. Over the coming years the top priority is therefore likely to be the optimisation of manufacturing processes in order to reduce costs. In the solar energy industry there are basically two strategies for cutting costs in PV cell and module production.

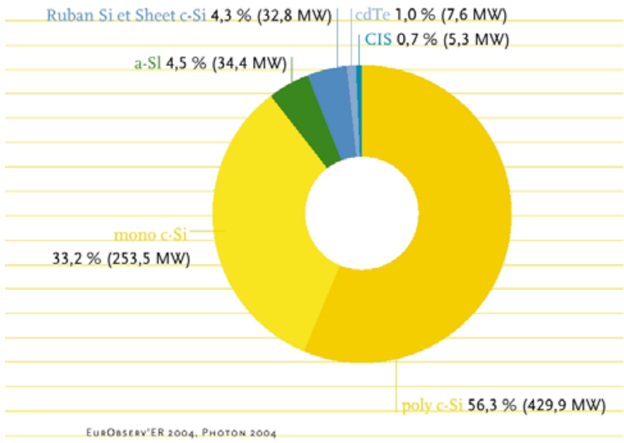

Figure 8: World production shares of various PV cell technologies for 2003, a grand total of 764 MWp [6].

In crystalline silicon technology, the focus is on the economy of scale effects provided by mass production, larger and thinner wafers and improved efficiency. Most manufacturers do not attempt to make any fundamental changes in the design and manufacturing of cells, and have still managed to achieve significant progress so far with this strategy. However, industry experts doubt that this is a feasible way of achieving the 1 EUR/Wp module cost, a level of cost required in order be a self viable technology.
The second strategy that manufacturers pursue is to research innovative materials and technologies and try them out in pilot production. These measures require intensive research and are very risky, but the potential they offer is the achievement of cost savings in the long term to ensure that solar energy continues growing when crystalline silicon wafers are in short supply.
The involvement of the large petroleum companies (SHELL, BP Solar) in the PV technology was initially considered as their disposition to present themselves as ecological sensitive enterprises. But their continuing investment in this field proves that they have entered to diversify their investments and make a profit as in a few decades the grand era of oil will be over. Consequently, they have begun gradually to invest in the field of Renewable Energy Sources (PV, Wind, Biomass, etc.) as well as in new fuels, like hydrogen. Among the most well known and frequently quoted studies in terms of the projected energy technologies share in the future are the SHELL global scenarios which are being updated regularly [7]. SHELL is noting that around 2020, oil will begin to decrease its share and renewables will take off as one of the major energy resources. Furthermore, around the year 2050 at least half of SHELL's portfolio investments will concern the

renewable energy sources (RES) while it forecasts that on 2050, 50% of the world energy demand will be covered by RES, with the larger contribution coming from PV. SHELL places 3% of its investments in the RES field. BP and other competitors have similar plans.

6 PV Silicon feedstock shortage

Silicon is the second most abundant element in the crust of the Earth (27%), but it does not occur as a native element because SiO_2 in the form of quartz, quartzite, and other compounds is more stable. Many processing steps are conducted to bring Si from its native ore, quartzite, to the crystalline substrates used for solar cell fabrication or integrated circuit (IC) components. The starting silicon for both PV and IC applications is 99% pure metallurgical-grade (MG) Si obtained via the carbon reduction of $Si0_2$ in an arc furnace. The major impurities are Fe, Al, and C. This MG Si material is inexpensive (~$1/kg), but the residual impurities degrade carrier lifetime to unacceptably low values. Chlorosilane purification and deposition steps (used by the IC industry) increase the purity to more than adequate levels for PV use (99.999999%), but they also increase the cost to unacceptable levels for PV manufacturers. The current price of polysilicon from the chlorosilane IC process is about $50/kg, while PV users have a target price of about $20. So, the Si PV industry has been using reject material from IC polysilicon and single-crystal production - material that is too impure for IC use but adequate for PV use. The fact is that currently the PV and IC industry need each half of the world purified Si production of roughly 30.000 tons. The large polysilicon manufacturers are in the middle of expanding their production capacities and by 2008 there is going to be enough Si.

The downturn of the IC industry (2000-2003) temporarily relieved the PV feedstock shortage. The Si feedstock deficiency does not represent a fundamental material problem, because the technology, quartzite, and coke needed to make feedstock are in abundant supply. The issue is to supply feedstock with necessary but only sufficient purity (~99.999%) at an acceptable cost. The development of a dedicated solar-grade silicon process by several large silicon makers, as well as the strong, ongoing, effort by the industry to reduce silicon consumption per power unit produced, should allow the PV industry to continue to grow without any hinder. For the time being, thin-film technology will continue to grow in parallel to silicon wafer-based technology, particularly in areas where lower power is acceptable.

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