Armenia Renewable Resources and Energy Efficiency Fund
Renewable Energy Project

TASK 3 – MARKET PENETRATION PLAN DEVELOPMENT AND SUSTAINABILITY RECOMMENDATIONS:

FINAL REPORT

"Assessment of PV Industry Development Potential In Armenia"

This work was implemented with support of Global Environment Facility and the World Bank under the Renewable

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0. EXECUTIVE SUMMARY

Task 3 Report under “Assessment of PV Industry Development Potential In Armenia” project describes in detail the production of selected technological chain - PV solar modules based on Poly-silicon and Upgraded Metallurgical Grade (UMG) silicon blend. The chain covers mining of quartzite, processing for metallurgical silicon, production of UMG silicon and poly-silicon, blending process, production of ingots, production of wafers and solar cells, to produce PV modules.

Assessment of the international market potential for the selected technology/product shows possible scenarios of international market development while the local market potential evaluation shows the potential for PV products both in terms of off-grid and grid-connected applications.

One of the key factors for PV industry development is the introduction of favorable legislation and regulation that supports the use of PV technologies and the development of a PV industry. To this end, this study reviews and evaluates the international experience in promoting PV industries and identifies critical barriers that could hamper the development of PV technologies in Armenia.

The Report presents a road map for market penetration along with recommendations on how to make both the regulative and legislative environment in Armenia more attractive for developing the PV industry.

As a key for supporting PV industry development in Armenia, the government should come up with sound incentives in regulative and legislative area. Attractive tariff for grid connected PV power plants will encourage both local and foreign investors to finance and develop PV projects. Mandatory requirements to integrate solar technologies along with other energy savings measures and attractive retail financing will enable development of local market for PV products. Finally, tax privileges will be necessary for the new industry development.

1. INTRODUCTION

As it has been indicated in the Task 1 Report, the photovoltaic (PV) industry has been growing internationally at an exponential rate. There is a huge demand for solar grade silicon (poly-silicon) of which more than 80 % is produced by a classical method. Armenia has experience in PV technologies and has significant deposits of raw materials. Along with existing infrastructure (with certain upgrades or modification) as well as the experience and skills of local R&D institutions, Armenia can meet the requirements for the development of a PV industry.

The main objective of the Task 2 Report was to identify and assess those PV technologies that apply to Armenia taking into account the country's comparative advantages. One of major factors that makes Armenia competitive in PV technologies development can be considered the existence of a wide variety of siliceous raw material from various sources and morphology in the territory of Armenia. The Report evaluated those technologies which are considered most suitable for Armenia (based on the level of commercialization, access to the markets and international market development forecast). It makes comparative analyses of the pre-selected technologies in terms of cost of production, potential ecological impact and risk mitigation, benchmarking and economic evaluation.

As such, the production of PV solar modules based on poly-silicon and Upgraded Metallurgical Grade (UMG) silicon blend was evaluated to be the most economically viable option for Armenia . The production includes mining of quartzite, processing for metallurgical silicon, production of UMG silicon and poly-silicon, blending process, production of ingots, production of wafers and solar cells, and production of PV modules. All this can be accomplished under certain favorable conditions, such as low product cost and market price, and one should expect development of poly-silicon and UMG-silicon blended technologies as the most promising for Armenia.

The major objective of Task 3 is to assess the international market potential for the selected technology, to evaluate the local market potential for PV products both in terms of off-grid and grid-connected applications, to evaluate international experience in promoting PV industry as well as critical barriers that hamper PV technologies development in Armenia. The report ends up showing a market penetration plan along with recommendations on how to make both regulative and legislative environment in Armenia more attractive for developing the PV industry.

2. MARKET PENETRATION PLAN

2.1 Technology Chain

The general scheme of the technological chain, recommended for Armenia is as follows:

- MG Si production based on mineral quartzite.
- Poly Si production by Siemens process from the MG Si.
- UMG Si production by combination of chemical and "Elkem" processes from the MG Si.
- Poly-Si /UMG Si blend production.
- PV cell production.
- PV module production.

Within the territory of Armenia with the well-developed infrastructure, there are a number of promising deposits of high quality, relatively pure, quartzite minerals (silicon dioxide), which can be optimally chosen for the regional production of poly-silicon, employing the full technological scheme.

Preparation of the raw material in the recovery process consists of two simple operations of powdering (grinding) and washing of quartzite.
To change silicon into polycrystalline silicon, metallurgical silicon is manufactured from quartz with a purity of 99% through a well-known carbon thermal process.

The metallurgical impurities of typical metallurgical-grade silicon are as much as six orders of magnitude worse than that of typical solar grade silicon. Therefore, additional purification is needed in order to obtain solar grade silicon.
In conventional poly-silicon production by Siemens process the trichlorosilane is decomposed in the presence of hydrogen with the deposition of poly-silicon on thin silicon rods.

Basic technological stages of Siemens process based on interaction of powdered metallurgical silicon with HCl are: synthesis of HCl from chlorine and hydrogen, synthesis of trichlorosilane by silicon hydrochlorination, deducting of vapor-gas mixture, condensation of chlorosilanes, hydrogen reduction of trichlorosilane, etc.
To receive UMG Si, metallurgical grade silicon is pyrometallurgically upgraded and refined. Depending on the crystallization technique a final purification is done. After this complicated series of steps, the UMG-Si is finally ready for crystallization.

To reduce the cost of initial material, an additional chain with poly-Si /UMG Si blend is proposed. A *mixture* of high quality poly-Si and relatively low quality UMG Si will provide a better quality initial material making it acceptable for competitive PV products manufacturing

In Armenia, there are many years of experience of using different crushing-sorting machinery by many construction and road-construction organizations and companies.

In the context of the current project “Nairit”, CJSC and “Prometey Khimprom” JSC (former Vanadzor Chemical Factory) are the best prepared factories by their industrial structure, technical and territorial capacity for possible realization of metallurgical silicon and poly-silicon production in Armenia.

The scientific potential does exist, which allows creating a group of specialist who can organize the production of metallurgical silicon and polysilicon, as well as other chains of the PV industry. A strong collaboration between local and international industry needs to be developed and priorities need to be established on national level facilitating the local PV industry development.

2.2 International Market Potential

The study focuses on PV modules based on c-Si cell made of UMG and blended polysilicon material. The international market potential needs to be assessed in the development of the market, the production, the technology and the cost. Next, the identification of competitors and assessment of their position and products should be done. These assessments lead to the potential of the discussed product in the global market and consequently to a market penetration plan (chapter 2.4).
Note; development of the market is very strongly dependent on political goodwill. 90% of the global markets are based on grid-connected PV applications, which in turn are 100% driven by supportive policies. With any new policies introduced or existing mechanism revised, the market will get either a boost or slowdown. A good example is the market development in Spain; in 2008 it was a fantastic boom but in 2009 could be a significant slowdown or even a bust..
The market development drives the production and cost development and indirectly also the technology improvements. The following assessment is based on the status quo as per mid of January 2009. Please note, with possible ease of access

to financed projects and manufacturing in 2009, for example. in the USA or Germany, these two markets have the potential to explode as uncapped markets, and change our market potential perspective. We try to give both a pessimistic and a progressive scenario herewith.

Market development

The market development was described extensively in the phase 1 report. To forecast a market development one needs to understand the past of market development and the key market drivers. The market drivers are presented in chapter 3.1. Here is an overview of how the recent history of solar looks like: In 2004-2005 Germany, with its uncapped FIT program has been setting the pace and PV has become en vogue in Europe. New (or adjusted) FiT programs were in discussion in Spain, France and Italy. Spain promised to become the new 'El Dorado', and Germany was the world champion in terms of installed PV capacity and production.

In 2006-2007,the 'Big Hype' of PV Solar stocks outperformed the general averages (DOW, NASDAQ) by as much as 20-fold. Following the bottleneck of poly-silicon supply, thin film technologies experienced a revival and used the window of opportunity to make a significant dent into the market:Industry and the general public really seemed to focus on thin-film technologies and their longer term potential.

In 2008,the Solar Stock collapsed. By October 2008, the PV party came into a crashing halt. As a result of the global credit crisis and solar stocks (market capitalization of companies) were down around 75% on average. In Q4 companies started to revise their targets and expansion plans for 2009. Upgraded metallurgical (UMG) silicon was the big news and offered promises of significant cost reduction for c-Si modules, making it competitive with thin film technologies.

In spite of these setbacks, Q 4, 2008 was an exceptional year, driven by strong growth in Spain and Germany, resulting in a growth rate year to year (GRYoY) of 74% compared to last year's 37% annual growth rate thus causing module prices to increase from 5% to 15%. The annual installed capacity is estimated at around 4,100 MWp. Grid-connected centralized application (shaded in blue) has experienced the highest growth rate (a factor of 1.8). However, distributed grid-connected applications represent still the largest share and account for 71% of the cumulative global installed PV power.

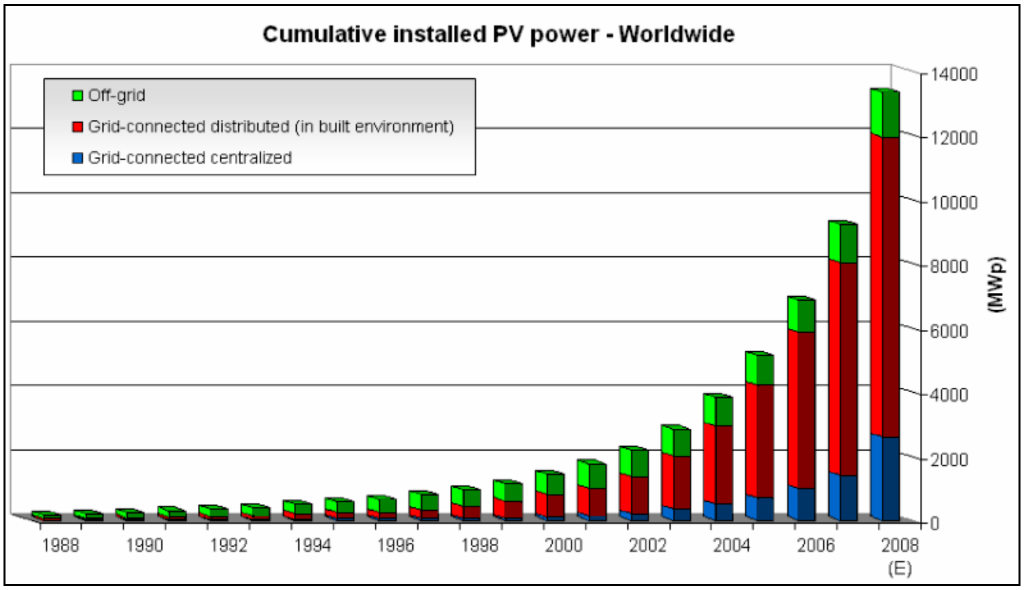


Figure 1: Market development 1988 to 2008 (Ref: Navigant, Photon International, EPIA, 2008 estimated by Envision)

In 2009, the growth rate is forecasted to return to the growth level of 2007 and one can expect declining module costs, because of the financial crisis. Industry is upscaling fast to achieve module production costs of less than Euro 1.00/Wp. Several voices say the worst is yet to come towards the second half of 2009 or even the beginning of 2010. The threat of oversupply, the volatile currencies and less generous subsidies will put further pressure on all companies. The very attractive subsidies experienced in uncapped markets such as Spain, Korea, and Germany are unlikely to be replicated in the future given concerns or even fears of their ultimate cost in a worsening world economy climate.

However, nothing is fundamentally wrong with the PV technology. Photovoltaics is a reliable and proven technology for producing 'clean' electricity for over three decades. A number of PV technologies are ready for prime-time, and can compete with conventional energy producers on a peak generating level. Future generations will achieve even further cost reductions and will enter the mainstream in less than a decade in developed countries. The outlook for PV is strong and it is anticipated that the business will recover in a few years time.

However, starting in 2006 until mid 2008 PV technology (and thus the industry) was "flying too high and soared towards the sun without the right wings to support it". The much needed market consolidation, coupled with the global financial crisis brought the “high-flyer” back to earth and now a wave of companies are scrambling to their feet to understand the impact and adjust to the new scenario. We will see in next two to four years a major shake-out in the overly crowded solar energy space – starting with crystalline silicon PV modules and spreading to the thin film sector.

Eventually, the weak and inefficient players, with inexperienced and poor management, and low quality products that are not competitive will get weeded out. Considering a pessimistic scenario under the current economic crisis, the PV industry could be heading for significant capacity oversupply in the next few years (figure 2). If Japan is indeed introducing a new sustainable and attractive PV policy, the markets in Europe develop without the barriers experienced earlier (e.g. France, Greece and Italy), and the US can get back on track with project financing, the oversupply will lessen (progressive scenario). However the oversupply could still be between 50% to 70%.

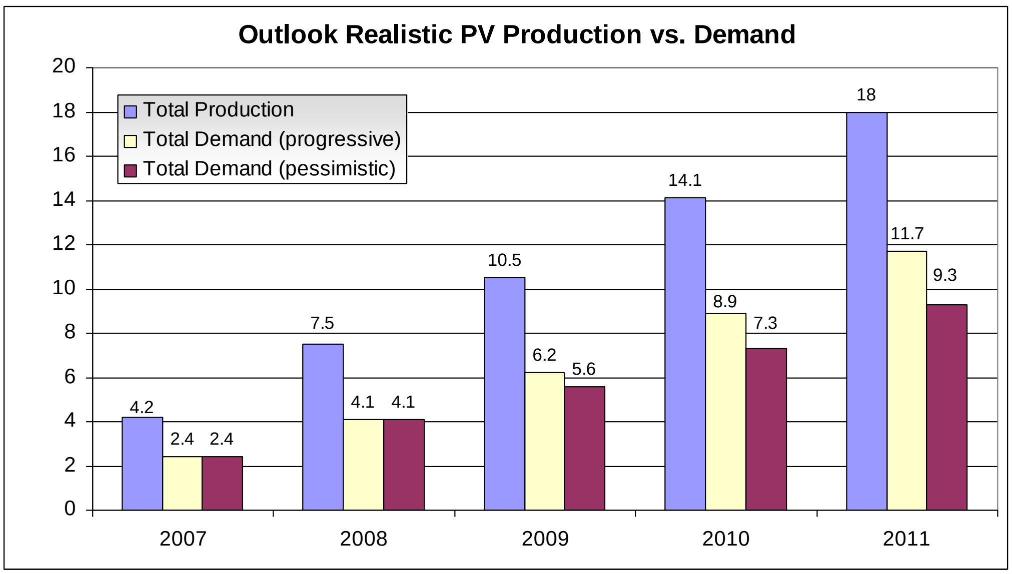


Figure 2: Outlook realistic PV production vs. demand until 2011 (Ref: Envision, Jan 2009)

Thus, with PV demand increasing at a slower rate, and PV supply continuing to grow rapidly, it is estimated that PV ASP (average selling price) will fall in the range of 10 to 25% in 2009. Profit margins will be shrinking to a point where higher-cost module manufacturers will not be profitable anymore in a future strong competitive climate.

Companies started in 2007, following the market hungry for PV modules, will have difficulty to survive, as most of them are small and do not have enough cash to weather out the storm. In China alone, there are over 100 module manufacturers and the first signs of several smaller manufacturers stopping production or are actively looking for a take-over partner is a case.

In spite of the above mentioned problems for PV industry, it can be easy to lose sight of the long-term potential of the PV technology. The market forecast is positive. Reaching grid-parity will unleash unlimited market potential and drive large-scale manufacturing towards competitive prices versus conventional energy sources.

Based on recent EPIA study (figure 3) the market will continue to grow exponentially, and China and South Asia are expected to become key markets towards 2025 to 2030. In a *moderate scenario* the business potential in 2015 could exceed Euro 50 billion, with 40% turn-over generated in Europe. The USA and Canada will become important markets until around 2025, after which the Asian markets will take over.

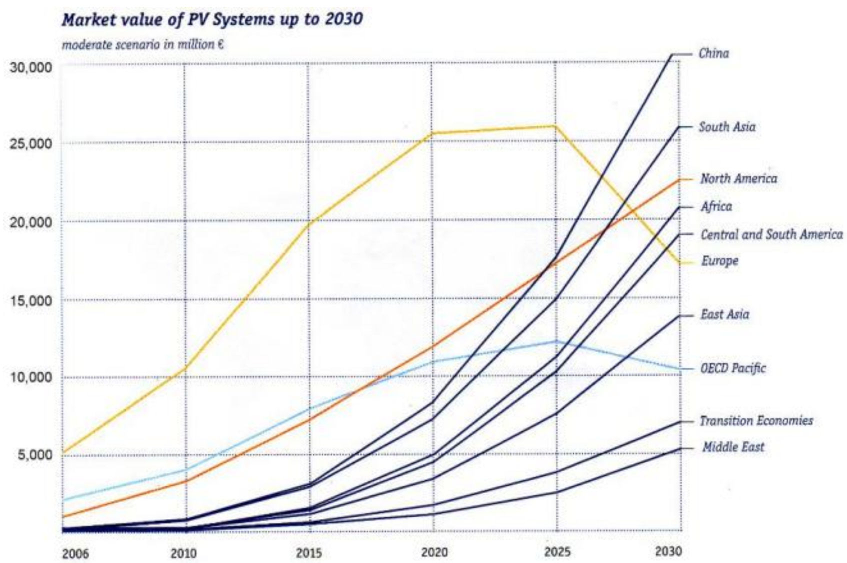


Figure 3: Market value for PV systems until 2030 (Ref: EPIA, 2008)

To achieve this compound annual growth rate (CAGR) larger than 30%, the anticipated consolidation, speeded up by the global economic crisis, will in fact turn out to be positive for PV. By shaking out the weak players, this will end the current fragmentation, cool down the over-heated market and facilitate the emergence of stronger industry players turning them into giants, with a game-changing ability to deliver massive economics of scale and thus become a serious contender among mainstream energy sources. Consolidation will create corporations that can weather the sector's inherent cycles and leverage their political and economical muscle to champion also in the future.

Production development

Today, more than 400 manufacturing plants world wide are counted in solar cell and solar module production.. Many emerging companies have been identified in thin films, ranging from amorphous, micromorph, CdTe to CIGS. Also in the next three years, the crystalline technology is upscaling fast, with several announcements in the gigawatt range (e.g. REC, Sunpower, Q-Cells and Suntech Power).

The crystalline technology, with mono c-Si (sc-Si) and poly c-Si (mc-Si) has dominated the market in the last thirty years and will dominate the market in the coming decade. However, thin film (TF) has a huge potential for cost reduction due to fully automated simple manufacturing techniques by e.g. screen printing or roll to roll sputtering and lower demand for the material resources, and thus will compete with c-Si technology much stronger in the coming years.

In 2009, it is estimated that TF will gain some market shares, but not exceeding 13%. Poly c-Si is estimated to dominate the market also in the coming years, largely due to the cost advantage of the material, and the improved material properties and thus higher efficiencies from upgraded metallurgical grade (UMG) silicon. UMG, either as source or as blended material, will open doors to significant cost reduction and in 2008 the first long-term contracts (e.g. Bécancour Silicon Inc/Timminco with Q-Cells) have been signed.

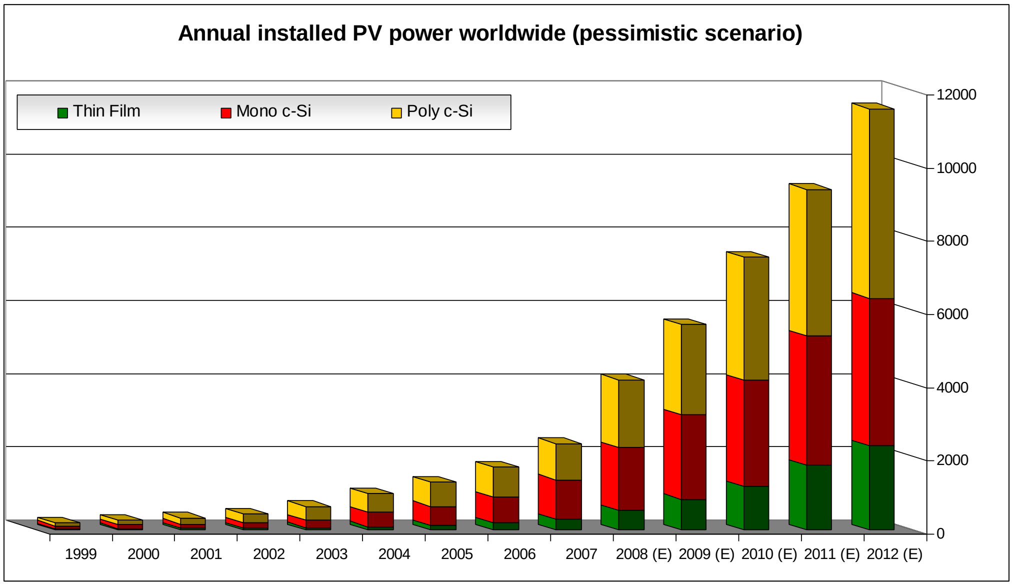


Figure 4: Overview PV cell technology market development (Ref: Photon International & Envision)

UMG silicon can be processed into poly c-Si ingots, wafers and solar cells, provided the UMG material meets certain quality requirements, which only a few can meet today. However, this is expected to improve in the next 2 years and will provide poly c-Si (and thus the crystalline) technology a cost-competitive solution to maintain a market share. Modules manufactured from UMG-Si material have significant potential for cost reduction. Today (Jan 2009) module production costs – based on the Siemens process – are between Euro 1.60-2.00 per Wp, thus for UMG PV modules, a cost reduction of around 50% can be achieved in the next few years, provided the benchmark price for UMG-Si of less than Euro 15 per kg can be achieved.

It is rather difficult to gauge supply from UMG in the next few years due to the simple fact that today few can master the process to produce high-quality UMG material, acceptable by cell manufacturers. However it is forecasted that raw materials from UMG process will increase significantly two to four years from now, as it offers the highest potential to drive down the cost. Figure 5 provides a perspective of the production development of raw material in percent.

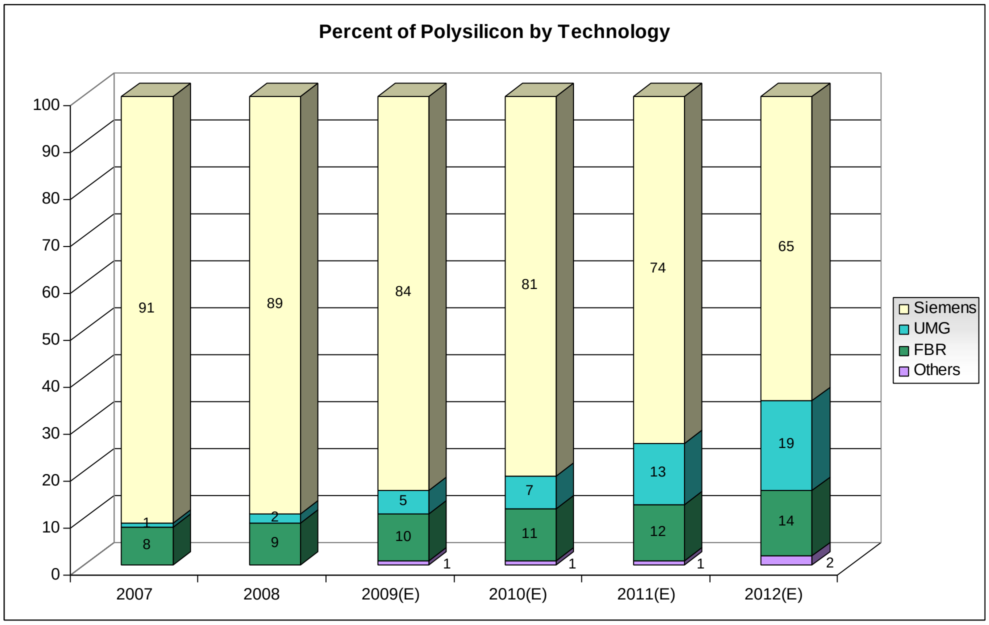


Figure 5: Development of poly-silicon by technology (Ref: SolMic, Prometheus and edited Envision)

Since 1999, we have experienced a doubling of PV production capacity every two years and it seems this trend will continue, taking into consideration the recent announcements of the various global PV players and new - but yet to be proven - technologies coming on line. This means increasing worldwide production capacity from 4.2 GW in 2007 to ~14 GW by 2010, resulting in a growth rate exceeding 50%. Photon International forecasts even an annual PV production capacity of 26 GW by 2010.

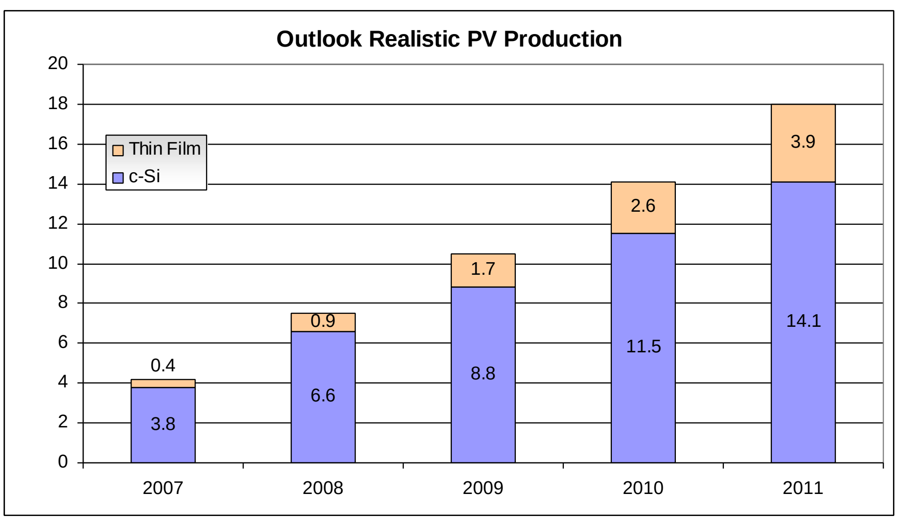


Figure 6: Outlook PV production development from 2007 to 2011 (Ref: Envision)

TF is projected to increase the production share to around 18% in 2010. However, crystalline technology will dominate the future market in the next ten years. UMG material is estimated to contribute in 2010 approximately 800 MW manufacturing capacity.

In 2008, among the top ten PV producers were nine companies producing crystalline products and only one company (First Solar) manufactured TF modules. Leading the manufacturing business is Suntech Power (P.R. China) followed by Q-Cells (Germany) and Sharp (Japan).

Company	**Country Of Origin**	**Technology**	**Capacity 2008 (announced) (MW)**	**Rank 2008**	**Rank 2007**
Suntech Power Holdings Ltd.	China	Crystalline	950	1	3
Q-Cells	Germany	Crystalline	584	2	1
Sharp Electronics	Japan	Crystalline	500	3	2
First Solar	USA	Thin-film	484	4	5
SunPower Corp.	USA	Crystalline	414	5	12
Yingli Green Energy	China	Crystalline	400	6	9
SolarWorld	Germany	Crystalline	380	7	7
Solarfun Power Holdings	China	Crystalline	360	8	15
Sanyo	Japan	Crystalline	340	9	8
Kyocera	Japan	Crystalline	300	10	4
Total Top 10 (in MW) in 2008			**4,700**		

Table 1: Top 10 PV producers (Ref: Envision, Jan 2009)

From 2012 onwards, the worldwide PV production could grow at an even higher growth rate, depending if grid-parity is reached in certain markets. Several experts project to achieve grid-parity in 2010-2012 in few states in the USA, and by 2012-2015 in Spain, Italy and Japan. Obviously, as soon as grid-parity is achieved, the market will skyrocket and may not need an incentive PV policy, such as a FiT program.

Technology development

To master the UMG process and produce acceptable quality material for later producing ingots, wafer and solar cells production one needs considerable knowledge in order to succeed. It is much more complicated to process UMG material than conventional purified silicon in a Siemens reactor. In the case of UMG, the unusable portion of an ingot can be as large as 75%, very much depending on the quality of the material.

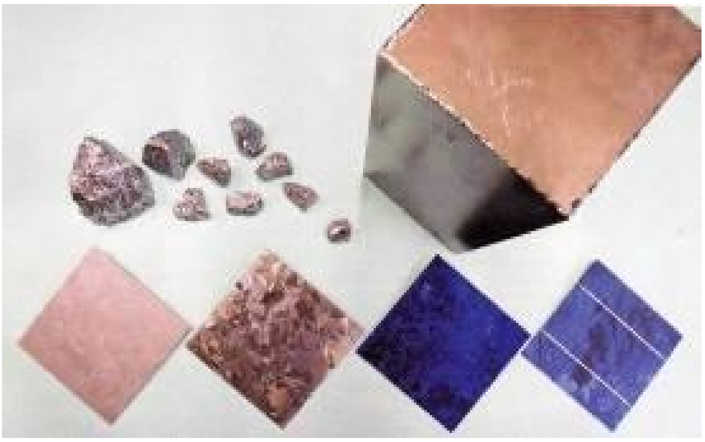


Figure 7: Value chain based on UMG products

Today, there are few suppliers for UMG material. These are: Timminco, Elkem and Dow Corning who have mastered the process to deliver good quality material. And all producers are aggressively pursing to improve their manufacturing process to have fewer impurities in the UMG material. Based on this raw material (100% or blended UMG silicon) from the few suppliers the first few products are available on the market.

Figure 8: UMG products

Currently the best commercial efficiency is from Q-Cells with 14.1%, and top efficiency of 15.4%. Standard multi-crystalline cells (mc-Si) can be 0.1% to 0.5% higher. Also test from Q-Cells show that the light-induced degradation is on average 1% higher than with mc-Si cells. Second, the fill factor and the open-circuit voltage are higher, and the short-circuit current and the breakdown voltage are lower. UMG based solar cells typically have substantially lower shunt resistance and a correspondingly lower value of breakdown voltage compared to conventional solar grade multi-crystalline solar cells. This fact imposes a limitation on the maximum number of solar cells that can be connected in series in the solar module in order to prevent irreversible breakdown in case of partial module shading during operation. The lower breakdown voltage indicates an increased risk for hot spots. The above mentioned peculiarities with UMG based PV modules require special attention in the design of PV system. Additional by-pass diodes or second junction box for the PV module may be required and thus increasing the cost for the PV system.

However, even if some additional BOS components are necessary and special attention in the design must be given – maybe just for the first few years until it becomes a mainstream product –, UMG based material are sold today for 15% lower prices than mc-Si products (example CSI during the Intersolar 2008).

Modules based on UMG material are expected to produce the same energy yield as with conventional mc-Si cells, and offer also the identical warranties. CSI has observed that UMG based modules perform similar to mc-Si modules. In fact, CSI is convinced of the promise of their product and are upscaling their production to half of their total module output.

UMG has a huge opportunity for PV and scientists are confident that they can improve the cell efficiency in the next four years to at least 18% and market cells for less than Euro 0.80 per watt by 2012. With continuing strong interest to use the UMG material the market is expected to react. It is estimated that next year at least 10% from the total c-Si module sales will be with UMG based materials. This positive momentum will be reflected also in R&D activities around the globe, to develop the technology faster than maybe even those with thin films. The industry is very upbeat on UMG material and based on the first results this year, the potential is very high to improve the electrical characteristics and drive down the cost, but it requires good in-house R&D facilities with experienced scientists or the right collaboration with an overseas partner.

Cost development

In 2007 crystalline solar cells (multi and mono) cost between Euro 1.62 to 1.98 per watt as figure 9 shows (Ref: Photon International in Q3 2007). The lowest cost can be achieved with multi-crystalline solar cells which are produced by Trina, Ersol, Yingli and Solarworld in figure 9. The production cost for mc-Si solar cells was around Euro 1.63 per watt in Q3 2007. Within a year and-a half manufacturing costs were reduced because of economics of scale but were also offset by increased silicon price. We estimate that the industry experienced still another reduction in their manufacturing of around 5%.

Thus, the benchmark value for mc-Si solar cells in Q1 2009 is approximately Euro 1.55 per watt. CSI sells their UMG products around 15% less than mc-Si, resulting in estimated UMG solar cell production cost of Euro 1.32 per watt.

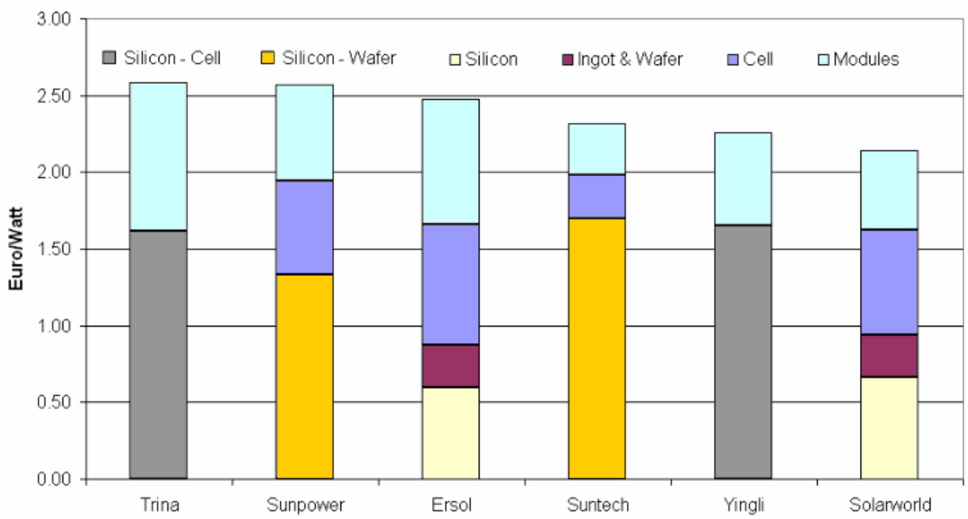


Figure 9: Overview of cost structure for c-Si cell (Ref: Photon International)

UMG has the potential to deliver solar cells for less than Euro 1.00 per watt in 2010 and Euro 0.80 per watt by 2012, based on estimates from Q-Cells, Calisolar and others. This confirms our cost structure proposed in the Phase 2 report(figure 3, page 11), however it emphasizes the benchmark price for UMG of less than Euro 15.00 per kg.

Module manufacturing cost depends on the production scale and the level of automation. In 2009, module production costs should be less than Euro 0.50 per watt in order to be competitive. for mc-Si modules between Euro 1.60 and 2.00 per watt in Q1 2009. UMG based modules are around 15% cheaper, resulting in Euro

1.40 to 1.70 per watt. Based on the FiT structures in many countries the industry is required to achieve cost reductions along the value chain up to 10% for an integrated manufacturing facility(e.g. Germany). Table 2 presents an estimate of benchmark production costs along the value chain for UMG module manufacturing in Armenia in 2012.

	Euro/Wp		
UMG silicon	0.23	-	0.28
Ingot & wafer	0.22	-	0.26
Cell	0.31	-	0.36
Module	0.25	-	0.30
Total	**1.01**	-	**1.20**

Table 2: Estimated benchmark cost for production of UMG modules in 2012 (Ref: Envision, Jan 2009)

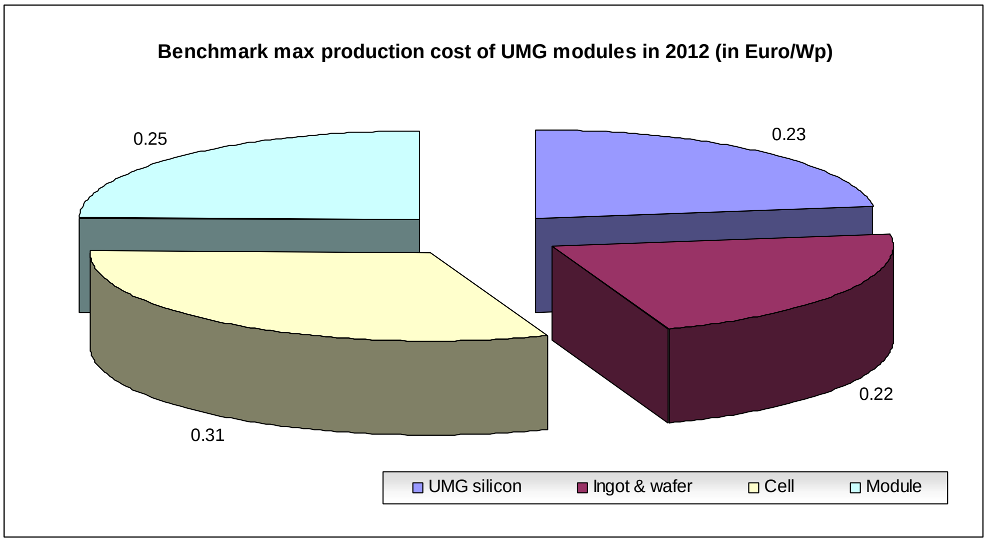


Figure 10: Benchmark max production cost for UMG based PV module for 2012 (Ref: Envision)

Production cost is strongly dependent on the cost for the high quality UMG material. If the benchmark for production cost and impurity level can not be achieved, the UMG material will not be competitive among the increasing number of UMG manufacturers.

Assessment of competitors

As per Jan 2009 four manufacturers are producing PV modules based on UMG material: Canadian Solar Industry (CSI), Photowatt, Trina Solar and Day4Energy. Following is a short assessment of these four companies and their status quo, although because the products are relatively new, little information is available at this time. All manufacturers give a 20 year warranty on their products. Canadian Solar Industry (Canada/China): CSI produces around 20 MW e-Module (based on blended or pure UMG material). CSI plans to upscale in 2009 to 200 MW nameplate manufacturing capacity. There are two types of e-Module; mc-Si with power ratings from 170 to 200 Wp (6’’ cells), and sc-Si or mc-Si with power ratings 150 to 160 Wp.

Photowatt (France): Photowatt claims to run their complete manufacturing line for mc-Si module based on UMG material. This is around 30 MW nameplate capacity. In the modules, 5’’ cells are used, and the module type is labeled PW1400 with a power rating of 130 to 160 Wp.

Trina Solar (China): No information is available, only that the PV module line is named ‘MeSolar’ and achieves an efficiency of around 14%. They seem to use a 6’’ cell. Expect sales in Q1 2009.

Day4Energy (Canada): No information is available. It is unknown when Day4Energy starts sale of the UMG modules. A special feature offers Day4Energy; they used their proprietary Day4 Electrode and distributed by-pass diode technologies to integrate shading protection directly into the solar cells as opposed to the traditional approach that calls for by-pass diodes placed in the centralized junction box area on the back of the solar module. Due to the inherent flexibility of Day4 Electrode integrated by-pass diode technology, shading protection can now be distributed through-out the solar module reducing product sensitivity to changing solar illumination conditions and partial solar module shading in particular.

Conclusion

It has been a rough-and-tumble ride for many public listed PV companies lately and this will be ongoing or even intensify. Several of the currently publicly-traded PV companies will probably not survive the current global economic turbulence, coupled with an oversupply in the market. We will see increasing press releases announcing earnings warning, reduction in capacity yields, and expansion plans put on hold or postponed – also for UMG material.

Credit is tight and cash is even more so. A number of PV companies have major projects (power production or manufacturing) in the pipeline that seek finance to be implemented. They need to find a sizeable chunk of change in the tightest credit conditions seen in decades. Thus, the sector will see a wave of consolidation and take-overs from industrial giants, which has already started with companies like General Electric, LG, Samsung, Panasonic, Schneider Electric and others.

This is a good time for companies with cash in their pockets and an interest to enter the PV business long-term and make good money. The doors have never been so open for new investment in utility-scale solar power plants or new technologies to commercialize and upscale (e.g. UMG). However any new market entrant has to consider the business as long-term strategy, otherwise disappointment will soon quench this excitement. The macro and micro market forces will put a lot of pressure on industry and it will be challenging to meet market expectations. Winners will be companies with lowest cost per watt, as with First Solar that is right now in the best position. First Solar has a window of opportunity until newcomers master their innovative technology and are able to upscale. Many module manufacturers will be pressured to reduce their prices but still need to reach healthy profits. If they don't, companies could find themselves trapped with low margins and unable to raise money to expand and reinvest. All companies need to think very carefully how they will position themselves for a shakeout to take advantage of the next boom, which will be when grid-parity converges with the traditional electricity tariffs, which is not going to happen in most markets for another four to eight years. UMG is certainly one of the promising paths to achieve considerable cost reduction. Important is that one understands the difficulties and challenges associated with the production of high quality UMG material, and plans accordingly.

In the next few years companies are advised to set more conservative and realistically achievable goals, because we have seen in the last four years a lot of big promises from solar companies that have been unable to deliver. During the peak time 2006 until mid 2008 we have seen a lot of smoke and mirrors from companies that had zero experience and know-how, but were still able to attract financing and make quick profit. To design a realistic strategy for the next years, companies need to observe and understand how the market and the technology are developing.

One should expect few solar companies will survive the hard times over the next two to four years and we believe the future market will be controlled by few vertically integrated giants. They will be controlling the value chain and survive. Smaller downstream players will find themselves in niche markets, or so-called ‘stuck in the middle’, which will require strong flexibility, very good understanding of the market and development issues, hence have a sound business strategy to survive between the big brothers controlling the market.

Nevertheless, we could also have relatively unknown players as future winners. New companies can be successful providing they have a strong vision, a conviction that the solar energy market offers huge business opportunities in the long term and deep pockets to see them through a difficult start-up phase under the current economic conditions. Important is to see the bigger picture and the enormous business potential in a grid-parity market and strategize accordingly.

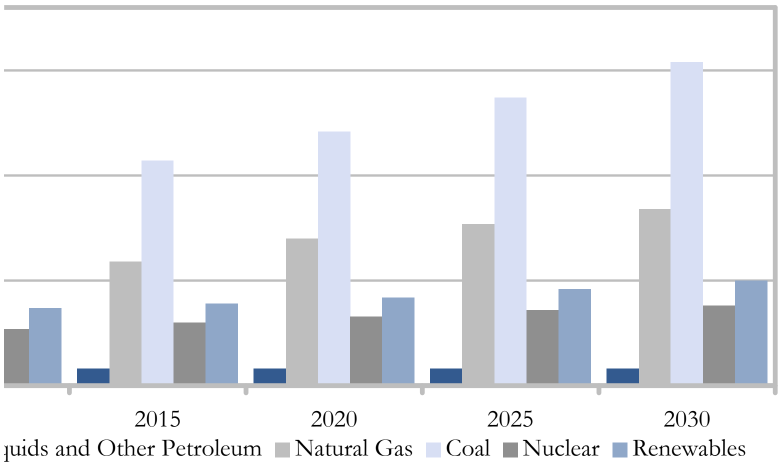
Presently and in the next few years the surviving companies will face a bumpy road ahead and as the economic sun is setting, thus it requires careful navigation to make it into the perfect sunrise and facing a long-lasting bright sunny day.

Strong growth in worldwide electricity demand

The U.S. Energy Information Administration (EIA) has estimated that the world will become increasingly dependent on electricity to meet its energy needs over the next two decades. Global electric power consumption is expected to increase by 58% between 2010 and 2030. This increase in electric consumption has been attributed to demographic changes, long-term growth in global GDP, and associated increases in global standards of living. This increasing consumption of electric power has driven demand for increased electric power production capacity. Financial costs have been a major impediment to the deployment of conventional electric generation technologies.

The U.S. Energy Information Administration has estimated that global increases in electric power demand will necessitate a near doubling of electric power generation between 2005 and 2030.

PROJECTED WORLD NET ELECTRICITY GENERATION BY FUEL[(a)]



There are barriers to building new conventional generation capacity. High materials costs, escalating replacement costs and highly volatile fuel costs (e.g., coal, gas) have caused the expected cost of newly constructed conventional generation capacity to rise significantly in recent years, a trend that is expected to continue. At the same time, environmental concerns about climate change and carbon emissions have imposed further costs on utilities planning to build conventional generation.

Strong demand growth for solar energy capacity

Solar electric systems provide the opportunity to cost effectively increase electric generation capacity while avoiding the environmental issues that increasingly preclude the construction and commissioning of conventional electric generation technologies. Currently, only about 0.01% of the world's power is generated from solar energy sources. Global annual solar demand is estimated to grow from 4.8 GW annually in 2008, to 20.1 GW annually in 2012, a 43% compound annual growth rate. By 2013, the global solar market is expected to exceed $100 billion in annual revenues, up from about $30 billion in 2008.

The rapid expansion of solar capacity in the utility sector is likely to be driven by a combination of existing direct financial incentives, renewable generation portfolio requirements and carbon emissions regulations. Moreover, additional and/or broader incentives or mandates (e.g., U.S. national RPS or carbon regulations), could further spur solar demand.

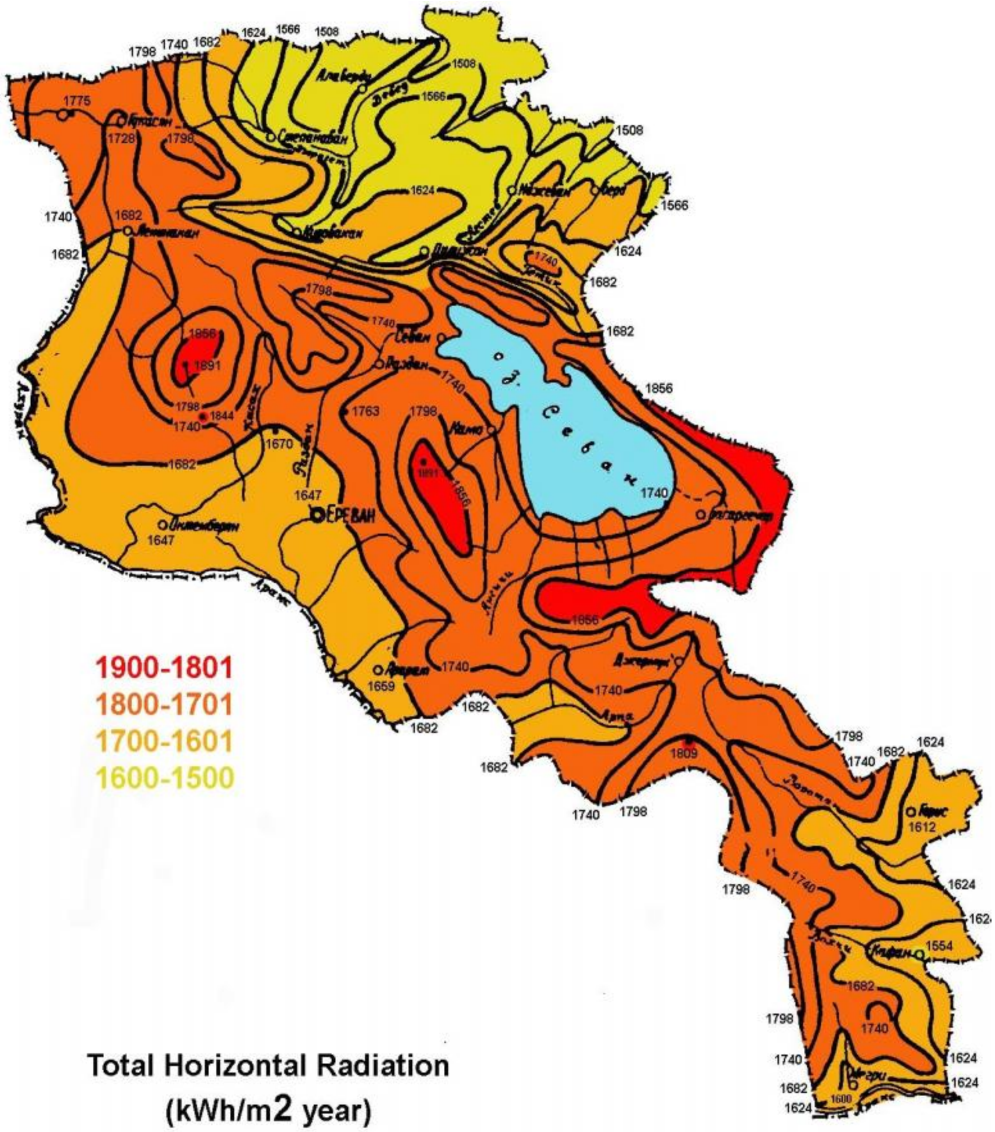
(a) Source: Energy information Administration.

2.3 Local Market Potential

With average elevation of 1,800m above sea level Armenia has a continental climate with hot summers and cold winters. Extreme temperatures of +45C in summer and -35C in winter are not unusual for some of the regions.

Due to its geographical conditions Armenia possesses a significant solar energy potential. There are 2500 sunny hours per year and the average annual solar radiation on horizontal surface is about 1720 kWh/m^2. The average data for Europe, for example, is 1000 kWh/m^2.

Updated map with solar radiation potential in Armenia based on radiation regime of Armenia has been prepared under the project financed by the World Bank through EnergyInvest Co. in 2005 is shown on the map of Armenia below.



In general the higher elevation in Armenia the higher solar irradiation can be expected. Uncertainty is sometimes affected by the presence of fogs.
Despite the significant solar energy potential, the number of solar projects implemented in Armenia are negligible at this time. Currently, over 2000 sq.m. of solar thermal (hot water supply) and about 40 kW solar PV are in operation.

Preliminary market survey done by SolarEn company in 2000-2001 identified the following market segments for solar PV:

Market Segment	**Potential Clients**
LOCAL MARKET	
Residential	Residential Housing / Summer Homes (net-metering or off-grid applications)
Recreation and Tourism	Hotels / Motels / Cottages / Resorts and Camps (off-grid applications)
Health Care	Hospitals / Clinics (back-up power supply)
Military/Defense	Military Bases (back-up, autonomous supply)
International Organizations	Embassies / Foreign companies (back-up power)
Agriculture	Farms / Rural Communities (PV irrigation, lighting)
Communication	Communication equipment (off-grid, back-up applications)
Entertainment	Cafes/Restaurants/Advertisement (off-grid and back-up power supply)
Grid-connected plants	Private and foreign investors (turn-key projects)
EXPORT MARKETS	
Private and non-commercials	Direct sales to privates or distributors (PV modules, other “chain” products)

At the same time, there is significant potential for utility scale solar PV applications (power plants). With highly developed power infrastructure, vast areas where no agriculture activities are possible and favorable climate the PV power plant can supply considerable amount of electricity to the grid. The study under EU/TASIC "Renewable energy Technical Potential of Gegharkunik marz of the Republic of Armenia" indicates that at regional level alone (with consumption at over 300 million kWh/year) the upper technical limit of solar PV penetration can be 25%. At national level this number can be 10% on average meaning significant degree of energy security for the country.

While for solar water heating the initial cost of equipment plays a major role for the consumers, in making them reluctant to install the systems (as well as the fact of subsidized costs for conventional sources of heat and hot water supply based on natural gas and electricity), the development of solar PV market is restricted mostly due to highly developed conventional power supply infrastructure and the absence of attractive regulation.

SWOT analysis

Developing solar energy business in Armenia at this stage is rather challenging. Solar PV technologies should compete with the major substitutive product such as electricity supply from conventional sources (based on natural gas and nuclear fuel) available in households, rural communities and commercial institutions.
On the other hand, the country can take advantage of opportunities for solar PV development and focus on *expanding export markets.* The SWOT analysis is provided in the table below.

Strengths	Weaknesses
• available raw materials to set up whole technological chain • local capacity and foreign expertise • legal and commercial possibility for decentralized grid-connected generation • local capability to absorb technology transfer and ability to develop and implement energy projects • available legislation to sell to the grid	• limited market • high initial costs • highly developed power infrastructure • in spite of the fact that promotion of renewables is stated as a policy goal in all official documents governing the energy legislative and regulatory framework, no specific legislation has been yet enacted and no well-defined mechanisms have been put in place to provide meaningful incentives for the implementation of projects in the area of renewable energy resources • lack of experience of foreign commercial banks in Armenia • lack of experience from local banks and lack of favorable credit sources (retail schemes) • lack of favorable regulative and incentive structure
Opportunities	**Threats**
• significant solar energy potential • EU and other donor and international organizations interest in renewable energy • favorable attitude public • possible increase of electricity price and need for new investment for conventional plants • exponential growth of international market • development of tourist attractions in off-grid locations	• nuclear power production is seen as a priority for the national energy strategy in order to meet the rising electricity demand; while refurbishing and further development of gas sector and gas burning plants will offer a strong competition to solar PV products • the existing hydro power, is perceived as covering the “clean energy” commitments • relatively high initial capital costs of renewables jeopardize the ability of solar energy to compete in a free energy market. • low energy prices due to existence of old plants and subsidized natural gas price, and excess of power from those plants • lack of political will to quantify externalities and energy independence benefits • lobbying power of conventional energy groups • unpredictability of local currency exchanges rates

2.4 Market Penetration Plan Development

Market penetration is defined as ‘depth of sales of a particular product in a given market’. Obviously the deeper the penetration, the higher the volume of product sales. We address in this chapter issues like target markets, niche markets, distribution, marketing, pricing, profit margins, capital investment, barriers and time frame.

This chapter is not a ready-made marketing penetration plan, but serves as guideline for a later detailed strategy that insures a consistent approach to offering PV modules based on UMG blended silicon material. We include few introductory words to give a better understanding and focus of the different scenarios for a marketing strategy, and be able to give sound guidance in this guideline of a market penetration plan.

In the follow-up process of creating a detailed marketing strategy one must consider many factors and objectives. In general these fall into one of four scenarios:

1. If the market is very attractive and the enterprise is one of the strongest in the industry they will want to invest their best resources in support of their product.
2. If the market is very attractive but the enterprise is one of the weaker ones in the industry they must concentrate on strengthening the enterprise, using their product as a stepping stone toward this objective.
3. If the market is not especially attractive, but the enterprise is one of the strongest in the industry then an effective marketing and sales effort for their product will be good for generating near term profits.
4. If the market is not especially attractive and the enterprise is one of the weaker ones in the industry they should promote their product only if it supports a more profitable part of their other business (for instance, if this segment completes a product line range) or if it absorbs some of the overhead costs of a more profitable segment. Otherwise, they should determine the most cost effective way to divest the enterprise of this product.

For present and mid-term global market environment and planned product, scenario 1 and 2 will apply and we have to select the direction most beneficial for the overall interests of the enterprise and for the product that will be most effective in the market. Following three strategies can be considered:

1. A **cost leadership strategy** is based on the concept that the enterprise can produce and market a high quality product at a lower cost than their competitors. These low costs should translate to profit margins that are higher than the industry average. Some of the conditions that should exist to support a cost leadership strategy include excellent access to funding for investment capital, on-going availability of operating capital, good process engineering skills, close management of labour, excellent access to R&D (either close collaboration or in-house), low cost manufacturing environment and low cost distribution.
2. A **differentiation strategy** is one of creating a product that is perceived as being unique "throughout the industry". The emphasis can be on brand image, proprietary technology, special features, superior service, a strong distributor network or other aspects that might be specific to the PV industry. This uniqueness should also translate to profit margins that are higher than the industry average. In addition, some of the conditions that should exist to support a differentiation strategy include strong marketing abilities, effective product engineering, creative personnel, the ability to perform basic research and a good reputation.
3. A **focused strategy** may be the most sophisticated of above strategies, in that it is a more “intense” form of either the cost leadership or differentiation strategy. It is designed to address a "focused" segment of the marketplace (often called niche markets) and is usually employed when it isn't appropriate to attempt an “across the board” application of cost leadership or differentiation. It is based on the concept of serving a particular target in such an exceptional manner that others cannot compete. Usually this means addressing a substantially smaller market segment than others in the industry, but because of minimal competition, profit margins can be very high.

Considering the above three strategies, the envisioned product (PV modules made from UMG/blended poly-silicon material), the low cost manufacturing environment in Armenia, reliable and good quality power supply and the easy access to high quality raw material, *strategy 1 is the recommended approach.*

However, if strategy 1 is selected, it is recommended that the interested party go vertically integrated all the way to downstream business (installation and PPA). Reasons; the current consolidation, speeded up by the global economic crisis, will shake out the weak players. This will end the current fragmentation, cool down the over-heated market and facilitate the emergence of stronger industry players turning into giants, with a game-changing ability to deliver massive economics of scale, and thus becoming a serious contender among mainstream energy sources. The consolidation is going to encompass further participation along the entire value and supply chain. For example, poly-silicon players, cell manufacturers and even power utilities will take control of their demand chain and can afford to, acquire suitable downstream players into their business portfolio, even in the current financial crisis. This will greatly enhance the control over the profit margins and revenue stream,. and the emerging industry giants (including the power utilities) will capture the majority of the potential future solar market, which is estimated to be at least 30 GW annually in 2020.

Strategy 2 is not recommended because it requires strong reputation. Also the objective for UMG based PV modules doesn't suit strategy 2. UMG based PV modules have to be lowest cost and not unique but rather mainstream.
Strategy 3 requires extensive market know-how to identify the small market segment, which is highly profitable. True, there will be such markets which will offer a highly profitable business, but if one identifies the wrong niche, the company will soon fail..
Achieving success with strategy 1 offers higher profits than 3, however also the CapEx are significantly higher. An interested party to set up manufacturing in Armenia should carefully assess his financial capabilities, the time frame for the business venture, in-house expertise and experience and potential partners. After this detailed SWOT analysis the party will be able to define the business strategy, either 1 or 3.

Strategy 1 offers excellent business perspective, but requires deep pockets full of cash and long-term planning; on the other hand strategy 3 is also an excellent opportunity, e.g. for a company with limited funding, but good market know-how and strong international collaborating partners. The two strategies are strongly dependent on the profiling of the company that is interested in starting manufacturing in Armenia. We do not need to discuss the strategies further, as they are part of the detailed market penetration plan based on the companies SWOT analysis and address now the general issue for any market penetration plan.

2.4.1 Target Markets

As per our assessment in chapter 2.2 and 3.1, the markets for the next ten years are in Europe, Japan, Korea and USA (please see also figure 3 in chapter 2.2). These markets (accounting for 97% in 2008) are driven by strong and sustainable policies and are also closest to grid-parity. Australia may emerge as a growing market in 2010/2011, however it would require 2-4 years to develop into a gigawatt market. China has revived talks on gigawatt power generation plants with PV and has announced to construct one project (1 GWp) in the Tibetan Plateau. We believe the market in China is very promising but for business planning purposes it is not sustainable at this time. Most likely China does not have the required staying power for at least the next five to eight years.

For the planning of an appropriate and successful business strategy the most promising markets are the ones close to grid-parity. In 2015 these include few states in the USA (namely California), Japan, Israel, Spain and Italy. In Figure 11, below the countries that are close to grid-parity are on the top right corner section (retail electricity rate for Armenia is close to 0.07 USD/kWh as of January 2009). Armenia is far from grid-parity, although it offers higher solar yield than many key markets, e.g. Germany, France and Japan.

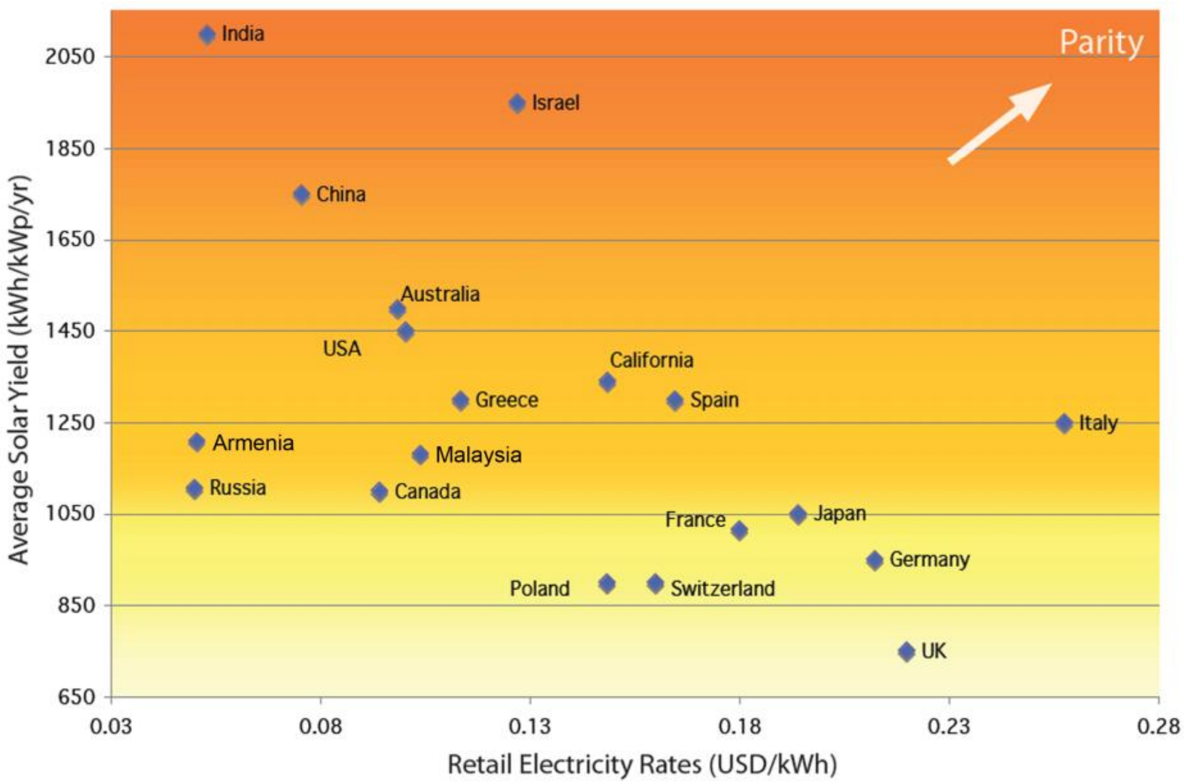


Figure 11: Proximity to grid-parity (Ref: Green Cross International)

When grid-parity is achieved, there's basically infinite demand and the market will shift back towards a seller's market.

Considering a ramp-up to full production in 2012 , we recommend the target markets as follows:

2012 (immediate)	Italy, Germany, Japan, California, Spain, Israel, Korea
2015 (emerging)	Australia, New Jersey, Texas, New Mexico, Arizona, France, Greece, Canada, Taiwan, Portugal
2020 (mid-term)	China, rest of Europe, rest of USA, India, Singapore
2025	South East Asia, ASEAN region, South and Central America
2030 (long-term)	Africa, Middle East, Central Asia

The above list considers the grid-connected PV market. The off-grid markets, also offer a good business perspective and are estimated to grow from the present 10% level into a gigawatt market, during the next five years. Still more than 2 billion people are without access to electricity (and often also clean water). This market was not well maintained in the last 4 years of the booming PV markets in Europe. The grid-connected markets paid higher profits for the products and offered faster business transactions, thus leaving the off-grid markets wide open for future service.

A new market entrant should consider a two-tier strategy, 80% focus on grid-connected PV applications (incl. BIPV and power plants) and 20% on off-grid PV applications.
To summarize, the target markets and focus on the applications until 2020 are recommended for a prospective business strategy as follows:

Grid-connected PV market	**80%**	**Target markets**
- BIPV - Power plants - Commercial plants	10% 50% 20%	- Germany, France, Switzerland, Korea, Japan - USA, Germany, Italy, France, Korea, Israel, China - Europe, USA, Japan, Korea, Taiwan, Canada
Off-grid PV market	**20%**	**Target markets**
- Telecommunication - Rural electrification	15% 5%	- Indonesia, Africa, Philippines, Russia, China, and many others - Africa, Tibet, Mongolia, South America, and others

2.4.2 Distribution

There are several methods to distribute the final product into the hands of the customer. These include:

1. **On-premise sales** involves the sale of the product using a field sales organization that visits the prospect's facilities to make the sale.
2. **Direct sales** involves the sale of the product using a direct, in-house sales organization that does all selling through the Internet, telephone or mail order contact.
3. **Wholesale sales** involves the sale of the product using intermediaries or "middle-men" to distribute the product to the retailers.
4. **Retail sales** involves the sale of the product through a full service retail distribution channel.

With the targeted PV module as the end product, method 2, 3 and 4 can be considered as distribution. At present, Method 2 is used as often, however we believe when PV becomes a mainstream product (in grid-parity markets) this method offers significant business potential, and few established companies today appreciate this possibility. The Internet is the future market place for almost all goods, including PV. Method 3 requires a good network of wholesalers and is the most often used distribution method in the PV business. This method has advantages (smaller company structure, focus on manufacturing, core business, flexible) and disadvantages (less revenues, no control over brand reputation, no control over interaction between wholesaler and end-user).

As explained earlier, the trend is towards a fully vertically integrated enterprise; to be able to control the upstream and downstream business. Based on this argument,, method 4 is recommended providing strategy 1 is pursued. If strategy 3 is followed than method 2 and 3 can be used for distribution.

2.4.3 Marketing

There are two basic marketing strategies, push and pull.

The **push** strategy maximizes the use of all available channels of distribution to "push" the product into the market. This usually requires generous discounts to achieve the objective of giving the channels incentive to promote the product, thus minimizing the need for advertising.

The **pull** strategy requires direct interface with the end user of the product. Use of channels of distribution is minimized during the first stages of promotion and a major commitment to advertising is required. The objective is to "pull" the prospects into the various channel outlets creating a demand the channels cannot ignore.

For both strategies PV events are *a must* to participate in by presenting the product and informing prospective buyers of the quality, the price and the strength of the company involved. Today, dozens of PV exhibitions are organised but it is often very difficult to identify those that are truly the ones leading the field.. As a rule of thumb, in the key, and also target markets, Europe and USA have led the industry guidance for years in all PV technologies. In Europe the EU PVSEC, and in the USA the Solar Power International, each attract more than 40,000 participants and at least 500 exhibitors.

Before embarking on any marketing activity, the product needs to undergo proper certification. In the PV industry this is the International Electrotechnical Commission (IEC). IEC has many standards for PV products, and with regards to PV modules (crystalline) the UMG/blended c-Si PV module needs IEC 61215 certification. The process can be rather lengthy – from 8 to 16 weeks – and the cost varies from test institute to another. TUV Rheinland is the most expensive were a module type certification (compliance test under IEC 61215) can cost between Euro 10,000 to 15,000. Another important certification is SK ‘class’ II (double insulated electrical appliance) approved. High quality products are all SK II approved and ensure safety for humans during installation and operation.
Before starting a marketing campaign the lengthy process for the certification needs to be factored in.

2.4.4 Pricing

Having defined the overall product objective and selecting the business strategy one must then decide on how the pricing of the product is structured. A pricing strategy is mostly influenced by the company’s requirement for net income and the objectives for long term market control. There are basically three strategies:

1. A **skimming strategy**; if the product has enough differentiation to justify a high price and the company desires quick cash and has minimal desires for significant market penetration and control, then one sets the prices high.

2. A **market penetration strategy**; if near term income is not so critical and rapid market penetration for eventual market control is desired, then one sets the prices very low.
3. A **comparable pricing strategy**; if the company is not the market leader in the PV industry then the leaders will most likely have created a 'price expectation' in the minds of the marketplace. In this case the price of the PV module should be comparably to those of the competitors.

Strategy 2 is pursued by CSI, who sells their UMG products for around 15% less than standard mc-Si products. This is clearly the **right approach** to penetrate the market fast considering that the business venture in Armenia, discussed above, becomes fully operational towards 2012. It is forecasted that we face still a significant oversupply of PV modules and any newcomer has to adjust his business and pricing strategy accordingly.
As per previous chapter 2.2 we forecast module production cost (based on UMG/blended poly-Si) in 2011 around Euro 1.10/Wp and in 2012 close to Euro 1.00/Wpk.
Average selling price (ASP) is estimated to decline as the market is saturated with PV modules. UMG products are to be 10 to 15% lower priced than mc-Si products to penetrate the market. We estimate for 2012 an ASP for UMG based products of less than Euro 1.30/Wp.

Of course, making a decision about pricing, marketing and distribution is heavily influenced by several key factors in the industry and in the market.

2.4.5 Profit Margins

Following is an analysis of potential profits and the factors that could influence the potential for generating and maintaining profits over the next years. Factors to consider include:

- Impact on profit margins is based on the competitor's resources, commitment to the industry, cash position and predictability as well as the status of the market.
- The intensity of competitive rivalry is measured by the number of competitors, size of manufacturing facilities, limitations on exiting the market, differentiation between products and the rapidity of market growth.
- The ability of the enterprise to limit suppliers bargaining power or to control the value chain.

We have discussed in chapter 2.2 the threat of oversupply, the volatile currencies (according to experts the Euro will weaken and the Dollar will strengthen in the next two years) and changing PV policies with less attractive subsidies than in the last four years. In general this will put significant pressure on all companies, thus on the ASP and in the end on the profit margin. We believe the profit margins will be in 2009 and 2010 still reasonable for established industry players with good quality products. An estimate is presented in table below:

Value chain	Profit margin (range)
Polysilicon (Siemens)	30-50%
UMG-Si	20-40%
Ingot & Wafer	20-40%
Solar cells	20-30%
PV modules	5-15%
BOS components	10-20%
Installation / M&E	5-20%

To forecast profit margins beyond 2012 – that is the earliest date we believe an integrated PV manufacturing facility in Armenia can be brought online – is very difficult. The reason is that it is unknown how the market demand will develop even considering two different scenarios, and how many new players enter the PV business and ramp up their manufacturing successfully. As a rule of thumb, upstream business brings the highest profit margins, in the range of 20 to 40% Polysilicon used to have higher than 50% profit margins in 2007.

A fully integrated manufacturing line can yield good profits, as one controls the value chain from the silicon to the PV module. Profit margins between 30 to 50% are common, if one masters low cost manufacturing and has good market penetration. For a new start-up in manufacturing of the target product (UMG blended PV modules) we believe the profit margins will be initially rather modest, because the start-up has to establish himself in the marketplace and penetrate the market with a new product. Building up the reputation and market a very competitively priced PV module will increase the market share and the profit margins.

2.4.6 Capital Investment/Target Manufacturing Capacity

Obviously the CapEx depends on economies of scale, choice of turn-key solution, infrastructure, etc. and running cost on the manufacturing location, the experience in technology and production, skill level of labour force, the ability to control the quality of raw materials and other factors.

We estimate in following two scenarios (plan A and B) the CapEx (equipment, infrastructure and buildings) and the running cost for an integrated facility in Armenia, starting operation in 2012. Please note the figures provided are indicative (Ref: Study by GP Solar, 2008) and need to be verified with actual quotations from turn-key equipment solution providers.

Plan	**Business strategy**	**UMG Si Target capacity (tons)**	**CapEx (Euro mln)**	**O&M (Euro mln p/a)**	**Ingot & Wafer Target capacity (MW)**	**CapEx (Euro mln)**	**O&M (Euro mln p/a)**
A	Cost leadership	6,250	600	35	1,100	420	47
B	Focus strategy	2,500	240	15	430	170	20
Plan	**Business strategy**	**Cell Target capacity (MW)**	**CapEx (Euro mn)**	**O&M (Euro mn pa)**	**Module Target capacity (MW)**	**CapEx (Euro mn)**	**O&M (Euro mn pa)**
A	Cost leadership	1,050	300	30	1,000	200	28
B	Focus strategy	420	120	13	400	80	12

A fully integrated manufacturing facility (UMG products) is estimated to cost in 2011 (purchase order issued):

Plan	Business strategy	Target capacity (MW)	CapEx (Euro mn)	O&M (Euro mn pa)
A	Cost leadership	1,000	1,520	140
B	Focus strategy	400	610	60

Following table – previously presented in Phase 2 report – has been slightly revised to reflect on CapEx estimates above.

Item	Cost per kg (Euro)
Quartz sand	0.50 to 0.80
MG-Si	1.00 to 1.50
UMG-Si (benchmark price)	10.00 to 15.00
Benchmark production cost (estimates 2012 onwards)	Cost per Wp (Euro)
UMG	0.23 to 0.28
Ingots	0.10 to 0.12
Wafer	0.12 to 0.14
Cell	0.31 to 0.36
Module	0.25 to 0.30

2.4.7 Criteria/Barriers

In the previous reports we have presented in detail the potential technical and non-technical barriers. In the following we summarize the different process features and the requirements associated, which can turn into barriers.

Process feature	Silicon to wafer	Wafer to cell	Cell to module
General technological level of production	Medium-High	High	Low
Level of process automation	High / Medium-High	Medium-High	Low
Involvement of special workforce	Medium-High	High	Low
Involvement of manual labour	Low	Medium	High

Sensitivity towards energy cost	High	Medium	Medium-Low
CapEx	High	High	Medium-Low

A few important criteria, which again may be barriers and have to be addressed in the planning stage:

Silicon to wafer	**Wafer to cell**	**Cell to module**
Availability of specialized technician and engineering staff	Technological level of local technician and engineering staff	Availability of cheap labour
Energy cost	Energy cost	Market vicinity
Incentives	Incentives	Transport infrastructure
Quality and reliability of technical infrastructure	Environmental regulations at location	Vicinity of support industry (glass, aluminium, EVA)
Vicinity of support industry and raw material	Vicinity of support industry	
	Dedicated science and university program to support local R&D	

Site selection – and thus the decision to establish local manufacturing for PV in Armenia – has to find the right balance between cost, human resource availability and technical infrastructure reliability.

Armenia offers a favourable manufacturing environment and can address easily several of above requirements and criteria; however the biggest challenge will be the CapEx, as it can easily exceed Euro 1 billion for an integrated gigawatt facility, as per chapter 2.4.6. Subsidies, incentives (e.g. tax holiday) and loans by the Government of Armenia will play the most important role in the decision process to establish local PV manufacturing.

2.4.8 Time Frame

The following schedule is indicative only, however it provides a good and realistic perspective on market penetration.

2009-2010 Discussion of results, SWOT analysis, negotiation with Government in Armenia for manufacturing incentives and loans, site location assessment, business plan development, access to finance, due diligence analysis, etc.

2010-2011 Decision process, tender and negotiation with turn-key equipment supplier and start construction.

2012 Delivery of equipment, start-up, fine-tuning, training and ramp-up.

The size of the manufacturing facility has a strong impact on the time frame, e.g. for gigawatt(1,000MW) fabrication we estimate around 3 years from decision to go, through start up of manufacturing, and for 200 – 500MW facility it can be between 1 and 2 years, depending on the value chain business and the local capabilities and expertise. Upstream business (e.g. solar cells) requires a highly trained work force to operate and to produce high quality products, clean rooms and sufficient space for the facility. For an integrated gigawatt facility, from ingot pulling to solar module manufacturing, land space of at least 60 to 80 ha is required.

We believe that a fully operational integrated gigawatt manufacturing facility can be operational in 2012 at earliest , providing no time is lost with access to finances and other decision making processes.

2.4.9 Conclusion

It is important to realize that the potential for market penetration involves whether one sells to past customers or new clients, and that how aware the clients are of the product quality, the pricing, competition, growth rate of the industry and emerging technologies. The success in the market penetration is dependent on a competitive pricing, quality, durability, reliability, fast deliver, additional benefits for the end-users, barriers to be removed and the credibility of the company itself.

We have discussed several scenarios for a market strategy and we summarize them as follows:

Plan	Prospective company (SWOT)	Business strategy	Distribution	Target capacity (MW)	Time frame
A	- financially very strong	Cost leadership	Retail (full control),	~1,000	2012 to

	- long-term prospective - going BIG		Internet		2013
B	- focus manufacturing - limited funding - good market know-how	Focus strategy	Wholesale, Internet	300-500	2011 to 2012

A critical factor in the development of the market penetration strategy is an honest appraisal of the strength of the enterprise. Factors to consider include:

- Enterprise capacity to be leader in low-cost production considering cost control infrastructure, cost of materials, economies of scale, management skills, availability of skilled personnel, R&D access and compatibility of manufacturing resources with product requirements.
- The competence of the management team and reputation of the enterprise.
- The adequacy of the enterprise's infrastructure in terms of organization, recruiting capabilities, employee benefit programs, customer support facilities and logistical capabilities.
- The freedom of the enterprise to make critical business decisions without undue pressure from outside influences.

As explained earlier, Armenia offers an excellent location for manufacturing of PV products. Reasons are; a politically stable country, an emerging economy, excellent access to raw material (high quality sand or also silica), lower labour costs, low electricity costs, has plenty of available land at low cost., and many other supportive factors.

However, one must also recognize the disadvantages: land-locked location and difficult access to main markets. No seaport is available and train transport is largely undeveloped and have to run through Iran, Georgia, Azerbaijan or Turkey – not an ideal situation.
In our opinion, the key for local manufacturing is with attractive subsidies, incentives (e.g. tax holiday) and loans by the Government of Armenia. If the disadvantages (mainly the logistics) can be balanced with attractive tax holidays and other incentives (training grants, free land cost, etc.) the decision process may become straightforward.

However, we need to highlight the fact that new manufacturing plans or expansions will be located relatively close to the key markets – Germany and USA – giving significant boost to the respective economies of those governments. The new investments are driven by strong local demand in USA and Germany, and priorities given to local manufactured products and the necessity to reduce the logistic costs by assembling the modules closer to the market itself. As module costs are declining fast in the next five years, transport cost will become increasingly costly for the end product, and counteract the low labour cost and attractive tax incentives given by overseas manufacturing locations.

This applies especially to thin film products were the production cost is already at Euro 0.80/Wp and could be reduced further thanks to fully automated production processes and increased in efficiencies. PV modules are a bulky item and require careful handling, and special packaging. Logistic costs will become an important factor in the next few years and should be reduced to be able to maintain a viable market position. With further cost reduction in crystalline silicon modules, e.g. solar cells made of UMG material, the logistic costs need also to be optimized by manufacturing closer to the installation area.

Thus, it is recommended that any prospective party who shows interest in establishing local manufacturing in Armenia, may want to consider limiting production to solar cells, starting with the raw material available in Armenia, then ship the solar cells and assemble the PV modules in the target markets outside Armenia.

3. SUSTAINABILITY RECOMMENDATIONS

3.1 Evaluation of International Experience to promote PV Industry and Market Development

Introduction

For over 50 years, photovoltaics has found many applications.. As the technology improved in efficiency and decreased in cost, new applications began to emerge. Consumer products (such as calculators) experienced high growth rate in the market in the early 1980's, but now represent less than 1% share of the overall market. From the mid-1980's to 1998 off-grid applications dominated the overall PV application market. From the mid-1990's to the present grid-connected PV has experienced significant growth and currently represents 90% of the annual PV installed. This market is also expected to continue to grow at exceptional rates for the next several years. Published data on the cumulative amount of global grid-connected PV, installed to date is indicating an annual growth rate (year to year) exceeding 50% over the last 8 years, making grid-connected PV the fastest growing renewable energy market in the world.

Today grid-connected PV provides only a small portion of the world’s energy, but is expected in the not so distant future, to provide the greatest share of the energy market when compared to all other available resources. It is for this reason that in the development of any Renewable Energy and Energy Efficiency plans,the grid-connected PV should play a key role.

The fantastic growth that is seen in grid-connected PV clearly demonstrates huge business opportunities that are available to those who desire to invest in this market, but it must also appreciate what the primary drivers are, until grid-parity is reached with conventional electricity power producers. Although the fuel (sunlight) for grid-connected PV is free, the capital costs of the technology still result in electricity production prices that are higher than conventional production prices (note: conventional prices do not include externalized costs). Forward thinking countries have dealt with this price difference through a range of support mechanisms to create a fair and level playing field as PV technology develops and approaches conventional grid pricing.

Market development

The regional distribution of the annual installed PV market in 2008 (estimated, Ref: Envision) is shown in figure 12.

Germany’s domestic installations take the major share with ~44%, followed by Spain (~24%), USA (~10%) and Japan (~6%). These markets are growing because of a combination of both past and present investments in the development and implementation of PV technology through a deliberate and consistent policy approach. In fact, from the estimated total annual installed PV capacity in 2008 (~4.1GWp) almost 90% depends on political goodwill. All this is the result of forward thinking politicians who have championed and succeeded in implementing a sustainable policy for the market development of the PV technology.

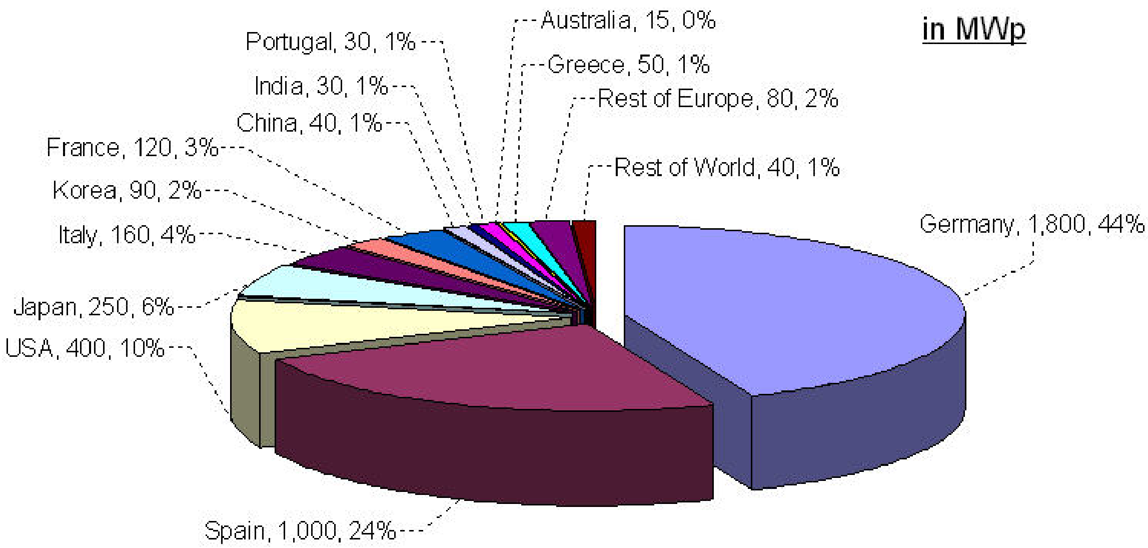


Figure 12: Regional market development in 2008 (estimated)

Figure 13 gives an overview of the market distribution and emphasizes the point that 100% of the grid-connected market depends on a supportive environment to develop the market until grid-parity is achieved. The off-grid market, accounts for around 9%, and is developing fast based on real market conditions (off-grid PV can be viable in many remote applications) and also donor programs. The consumer market is the oldest PV market and based on pure market play.

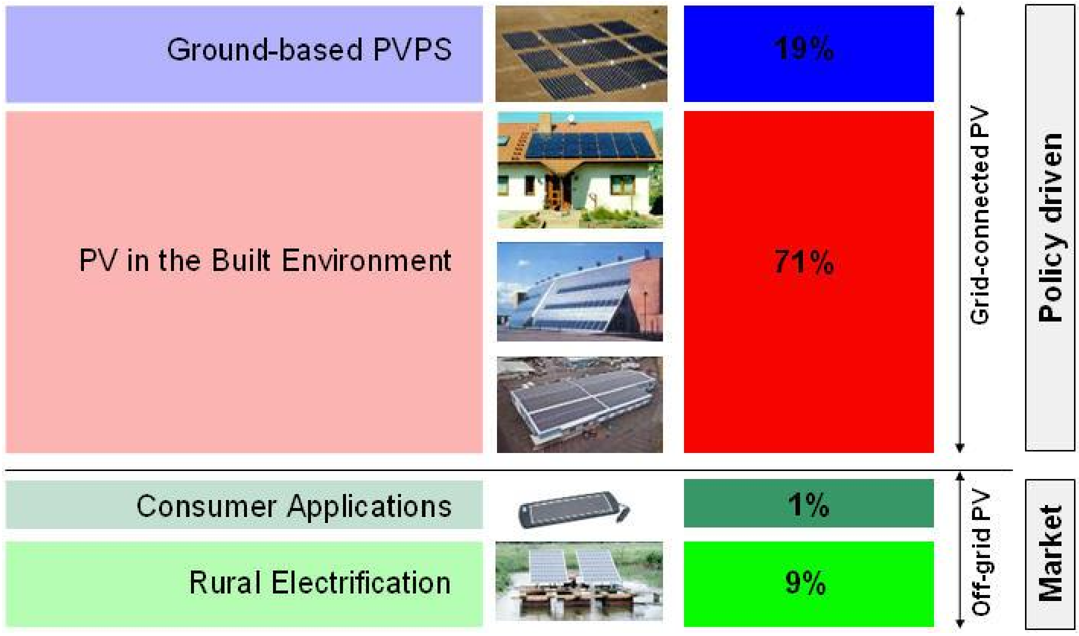


Figure 13: Overview application development in 2008 (estimated, Ref: Envision)

Market drivers – legislative and regulative measures

In the following we take a closer look at the key market drivers for grid-connected PV applications and present the available measures in EU, USA, Southwest and Central Asia, Russia and other key markets in Asia. Presently we can categorize the globally introduced PV programs based on six key policies. The table below provides an overview of the key policies currently implemented.

Policy	Description
Feed-in tariffs	Premium price for grid-connected PV electricity, paid to system owners by utility or regulatory body. Price typically guaranteed for 20 years.
Tax Incentives	Reduction or elimination of tax paid in purchase of PV systems, deduction of total cost of portion of PV system cost from business or personal tax
Renewable Portfolio Standard (RPS)	Mandatory portion of grid-connected PV power in the overall generation mix in the grid. Tradable certificates represent power produced by PV systems.
Net metering	Grid-connected PV produced electricity is used in the home or building where installed. Any amount above what is consumed in the building is exported to the grid. Any amount below what is consumed in the building is imported from the grid.
Direct capital support	Cash rebate on a portion of grid-connected PV system costs.
Green Pricing	Voluntary schemes where electricity consumers pay a premium for grid-connected PV power from utility or other electricity retailers. Power is purchased from grid-connected PV system owners.

Table : Key grid-connected PV support policy

Feed-in tariff (FiT) is the main policy driving the global PV market growth since 2000. In 2008, approximately 80% of the total annual installed PV capacity was in FiT markets alone. FiT encourages the application of grid-connected PV by paying preferential rates for the electricity produced. The rate or tariff paid for the electricity produced is typically set at levels that are believed to provide appropriate returns for the investment in implementation

and maintenance of the technology over an appropriate time period, generally in the order of 20 years. The rationale for the fixed rate over a long period of time reflects the fact that the main costs associated with deployment of such technology rests in the initial capital costs. The tariffs are usually differentiated by capacity and sometimes specific applications. The preferential rates are typically paid through a fund generated by a small tariff added to the price of the electricity over the entire electricity customer base. FiT policies can be combined with other support structures, but often the only additional support policy required to ensure success is the provision of low-interest loans that aid in reducing the burden of the high initial cost. Initially it may be difficult to garner interest from the financial institutions to provide such loans, but as the interest in the technology increases, it is likely that an increased number will develop and offer packages for such applications.
FiT is the most successful PV policy and has proven to provide the highest benefits, creates more jobs than any other policy, is the best tool for CO_2 emission reduction and has been most successfully implemented in over 50 countries worldwide. What makes a successful FiT? Long-term guaranteed payments that adequately reflect generation costs and profit need to be addressed. Also incentive levels that decrease over time, i.e. ‘tariff degression’ for new system installations but remain constant over the life of a given system. However each country has to find its own solution concerning the level of FiT and the funding mechanism. The goal is to push economics of scale in the PV industry by achieving a high level of sustainable growth benefiting the local industry mainly and to minimize the costs for the tax-payers. If the cost for PV becomes burdensome, this can produce very fast a backlash and kill any market.

Tax incentives can come in a range of approaches that may include addressing the tax structure of personal or business tax rates. These policies typically allow system owners to reduce the tax that they are required to pay and therefore it does not require the government or regulating body to provide money directly to the system owners, but rather decreases the net tax revenue that they receive from system owners. The tax incentives can be provided at federal, state/province or municipal level of government. Examples of potential tax incentives include:

- Accelerated depreciation of system costs for businesses;
- Tax holidays, either indefinitely or for a period, from revenue generated from installed systems;
- Elimination of retail sales tax on qualifying equipment; and

- Property tax exemption for the increased value grid-connected PV system adds to the value of the home.

Such approaches are typically used in combination with other support mechanisms as they do not in themselves provide enough financial incentive to encourage the deployment of systems. It is an important aspect to ensure that tax advantages that are available are taken into account with the overall support scheme that is chosen. This can prevent supporting the technology to a level that is too high and result in over heating the market.

Renewable portfolio standards (RPS) are directives by governments or regulatory authorities that mandate that a certain portion of the delivered electric power should be from renewable energy (RE) sources. It is normally the electricity grid operator, who is responsible for ensuring the target is being met by buying a minimum portion of RE generated power. RPS usually include some form of validation for compliance such as 'tradable certificates' referred to as Renewable Energy Certificates (REC's) for the power generated from renewable energy. Often these certificates represent a number of kWh's (usually 1,000 kWh's or 1 MWh). The certificates are traded between the renewable energy generator and the entity that must meet the obligation and then the certificates must be surrendered to the RPS authority by the end of the compliance period. The number of REC's must equal the compliance quota of RE and any shortfall will result in a penalty payment, where the penalty payment is generally designed to be higher than the expected market price for the tradable certificates. In its simplest form the RPS favors the cheapest RE sources, e.g. through a bidding process. Hydropower, wind power and biomass are more mature and therefore the respective REC's can be offered at a lower price than the REC's from grid-connected PV. However some RPS have divided the portfolio standard into different technology tiers or technology specific set-asides, so that the competition is between specific technologies rather than between differing technologies. When the addition of grid-connected PV is added, the tradable certificates are typically referred to as Solar Renewable Energy Certificates or SRECs. Without such technology tiers, grid-connected PV will not be supported by RPS.

Net metering is a grid interconnection and accounting approach that can be used for grid-connected PV systems. Using equipment approved by the regulatory body, electricity is produced on the same side as the customer's load, on the customer side of the electric utility revenue meter. When a net metered grid-connected PV system is employed the following scenarios existed for the use of the produced electricity in relation to the overall electricity required for the home or building:

- Produced PV electricity is less than the required electricity. Utility produced electricity is purchased to make up the difference.
- Produced PV electricity is greater than the required electricity. PV electricity is exported to the utility electrical grid from the home or building. The amount of electricity exported is stored as credit for the customer to be used at a later time.

The customer pays only for the net amount of electricity consumed in each billing period, and is sometimes allowed to carryover net electricity generated from billing period to billing period. Net-metering allows customers to receive retail prices for their self-generation.

Direct capital support programs target the main barrier of grid-connected PV – the high initial cost. By providing financial support towards the capital cost of the equipment the number of interested parties is enlarged as the net cost and potential financing requirements are reduced, so bringing the cost within their willingness and/or ability to pay. Grants must be of adequate size and must be predictable and consistent over time to be effective. The funding for such support programs is generally found in government budgets. Direct capital support programs can also be supplied by the utilities for promoting investments by the end-users. The success of financial incentives to encourage investment decisions also depends on whether the level of the incentive is adequate to bridge the gap between the market price of energy and the cost of renewable energy based on both the capital cost of the system and required maintenance. In the case of grid-connected PV systems it is typically found that these programs are combined with other financial mechanisms such as net metering or tax based incentives. Incentives should be gradually reduced and phased out over time to ensure that manufacturers and developers continue to improve the technology and reduce costs. A planned degression of the incentive will gradually prepare the market in advance for a situation where there are no more grants. Governments need to monitor capital costs and incentive structures over time to ensure an appropriate level of support is provide – not one that is inadequate to accomplish policy goals or one that overheats the market. This can be challenging, because capital costs tend to be driven by global market supply and demand, as the local market in one country is generally not large enough to drive market transformation and technological change alone.

Green Pricing involves the retailing of renewable electricity to customers at a higher price than conventionally produced electricity. This is typically a voluntary measure that is undertaken by an electricity retailer, electricity distributor or electrical utility. The organization intending to offer the electricity will either offer a given rate to producers of renewable electricity or open a bidding process with long term contracts (typically 20 years). Once the bidding process or long term contract is set, the organization can then sell the electricity to customers on a per kWh basis.

Depending on the blend of renewable energy (and at times cleaner energy such as natural gas based electricity production) the organization retailing the electricity will set the price for the given blend. If there is a high percentage of grid-connected PV electricity the price will be higher. If there is a higher percentage of other renewable such as wind power the price will be lower. Often several packaged choices are provided to the customer where they can choose either a given amount of electricity they purchase per month or can purchase all their electricity based on a given package.

Market overview

Following is an overview of the various global markets and the implemented PV policies. The **European Union** with its member countries is the biggest market globally and consumes 80% of the annual installed PV capacity. Since 2004, Germany has been the key market with 44% share in the global market. Germany was the first country introducing an attractive uncapped FiT to stimulate the PV technology and the respective industry. The annual PV capacity installed is estimated to have reached 1.8 GWp in 2008. In the past two years Spain became the new ‚el dorado’ similar to the gold boom in the past. PV has been hyped and supported by very attractive FiTs generating windfall profits. In 2008 the annual installed PV capacity was estimated at 1 GWp, representing 24% market share. Both – Germany and Spain – have revised their FiT program and lowered the tariff significantly and set new caps on the annual installed PV capacity. The initial reaction from the finance sector following the announcements was negative, however, coupled with the global financial crisis, it is forecasted that the module price will decline even more than the revised FiTs and thus make the two markets again viable and attractive. Other attractive and growing markets in the EU are Italy (globally No. 5 PV market), France, Greece and Portugal. These four markets are forecasted to consume in 2009 slightly over 1 GWp. The FiT policy is available in many other countries in Europe, e.g. Belgium, Luxembourg, Switzerland, UK (under discussion), The Netherlands and the Czech Republic. All of them offer attractive FiTs, which however do not contributet significantly to the global growth as the markets are limited in size. FiT policy is the chosen sustainable mechanism for developing renewable energy in Europe, well understood and fully accepted (20 out of 27 EU member countries have introduced FiT).

In the **United States of America** the market growth was about to come to an abrupt halt, when the Investment Tax Credits (tax incentives as key driver) were not going to be renewed in one of the last US senate sessions in September 2008. On 3 October 2008 however, became the big day and solar saw its Investment Tax Credits (ITC) extended by eight years as part of the Emergency Economic Stabilization Act of 2008. Growth rate of 45% in US PV installations was among the highest in the world in part due to new state programs (RPS mainly) and the ITC, and resulted in an estimated 400 MWp PV capacity installed in 2008. Utility-scale installations grew the fastest, accounting for 15% of the annual installed capacity. USA is worldwide the No. 3 PV market – estimated at around 1,200 MWp cumulative power – but could easily outpace Germany with the extension of the ITC and the various other supportive state programs. In addition to the eight years extension, the solar ITC has also been extended to utilities, which now can take direct advantage of the ITC through the ownership of solar projects. Not only ITC is an important driver in the US, but also the state RPS (renewable portfolio standards) program with different technology tiers and technology specific targets. In addition,net-metering is accepted in all states and a few states have even introduced FiT – but with much lower rates than in Europe – to stimulate the national and state growth of PV technology. The largest market in the USA is California, strongly supported by its Governor A. Schwarzenegger, who launched in January 2007 the ‚Go Solar California’ initiative. The new framework also included a major shift in the way solar incentives were calculated - away from a system that funded solar incentives based only on nameplate capacity and towards one where incentive levels are based on performance factors such as installation angle, tilt, and location. This performance framework ensures that California is generating clean solar energy and rewarding systems that can provide maximum solar generation. The California Solar Initiative is part of the Go Solar California campaign and builds on 10 years of state solar rebates offered to customers in California's investor-owned utility territories. In summary; the United States of America accounted for 10% market share in 2008 and offers a mix of market drivers starting with net-metering, direct capital support, tax incentives and renewable portfolio standards.

In **Southwest and Central Asia** the PV technology is fairly new and unknown. Off-grid, street and marine safety applications are the dominating business (estimated less than 5 MWp per year) in this part of the world and thus contributing to around 0.1% of the global market share. Grid-connected PV applications are starting to emerge, however not driven by any supportive policies or with an attractive feed-in tariff, but rather for showcasing or testing purpose. The Middle East countries want to establish the region as a leading hub for solar manufacturing thanks to low energy cost and plenty of available land and low-cost labor. The best know initiative is the ‚Masdar’ project in the United Arab Emirates with planned gigawatt manufacturing and a CO_2 neutral and zero-waste city, replying entirely on solar, wind and waste energy. It has become quiet lately, after much hype and press releases promoting the Middle East as best manufacturing location and sustainable living place.

Russia has no sustainable market driver for PV technology, but is well known for its strong poly-silicon manufacturing base. Several companies (e.g. Nitol, Aziel) have long-term poly-silicon supply contracts with global leading PV companies. Other companies have entered the downstream business (e.g. e.g. "Solar wind" Ltd. based in Krasnodar, Ryazan Metal Ceramics Instrumentation Plant Joint Stock Company of Ryazan or Bogoroditsk Plant of Techno-Chemical Products) and start module manufacturing. In last year the State Duma of the Russian Federation has adopted new eddition of the Law for Electricity Development. In accordance with this law different supporting measures including feed-in tariff will create legal basis for renewable energy development in Russia. By this state support it is expected to increase the share of rendewable energy generation in Russia from current 0.8% to 4.5% in 2020.

In **South, East and Southeast Asia** the key markets are Japan and Korea. Japan, still is No. 2 world market in terms of cumulative installed PV capacity, but this position may be contested in the next two years.. Growth in 2008 is estimated around 250 MWp, resulting in a cumulative capacity of less than 2,200 MWp. The problems for the limited market growth are well known. Firstly, discontinuing the national subsidy scheme (direct capital support) by end of 2005, and secondly, the local manufactured PV modules were exported to higher profit markets (Germany, Spain and Italy), compromising the availability of cheap modules for the home market. However, there’s a chance for a new incentive program for PV (Fukuda Vision), stimulating again the home market and the further industry development. For Japan, it was always a key objective to lead the global PV industry, and Japan was able to maintain this position for more than 8 years. The Government is aware, that to regain the top ranked position, a national PV program is required. It has proposed to have a USD 300 million program, again based on direct capital support, commencing in April 2009.

Korea was a highly attractive FiT market in 2007 and 2008. This was changed on 1st Oct 2008 with a FiT reduction of 30% for PV systems larger than 3 MWp. The announced tariff reduction will shift the PV market from large-scale PV system to PVPS with maximum size of 1 MWp or even smaller. Post 2012, the Korean Government has announced replacing the FiT program with a RPS policy. Considering the reduced FiT, it is expected that from 2009 to 2012 the Korean market will experience a growth rate of maximum 20%, unless the module prices falls dramatically and thus makes the 30% reduced FiT attractive once again.

Besides these countries, limited and often unattractive PV programs are available in few states in India and parts of China, Thailand, Malaysia, Singapore and Indonesia, with a mix of FiT, often for 10 years duration only, or with direct capital support.. The region (mainly Korea and Japan) takes approximately 11% of the global market and is expected to grow after 2020 faster than Europe and will overtake Europe between 2025 and 2030.

Benefits

In addition to the electricity generation and environmental benefits that grid-connected PV can provide, significant other benefits do exist. Today, countries that have been adopting a sustainable PV policy early on, are beginning to reap the rewards from their investments. These include: national based technological capacity, employment, green energy production (contributing towards meeting the Kyoto protocol targets), new large-scale high-tech industry and attractive local and global business opportunities. Benefits from employment and creation of a new industry need to be recognized when considering the support for grid-connected PV installations, or manufacturing in Armenia.

The employment opportunities can be roughly divided into the PV service sector and the manufacturing sector. PV service sector depends mainly on a supportive PV policy, whereas the manufacturing sector can grow because other attractive incentives are available in establishing local production. The job potential in this area will vary significantly based on which components are manufactured. Some manufacturing, such as cell production or thin-film module production can be highly automated and therefore will require less human capital.

A well developed and supportive PV program will encourage direct foreign investment (DFI). It is a known fact that an increase in the number of manufacturing companies will encourage the setting up of manufacturing facilities in a country with a strong local market related policy. The integration of both installation and manufacturing provides opportunities for technology uptake in the local market along with enabling real world application and testing of locally manufactured products. The environmental benefits of the technology are also improved with local installations, by reducing the shipping that would be required prior to system installation. To attract companies to Armenia, existing initiatives for local manufacturing could be adjusted to improve the conditions for grid-connected PV technology and to integrate seamlessly with a well supported Armenian grid-connected installation market.

Recommendations for Armenia

In designing an effective policy mechanism to drive the Photovoltaic deployment in Armenia, the following criteria need to be carefully considered:

- Simple approach and one that does not depend on a combination of many support mechanisms;
- One that promotes maintenance and continued operation;
- One that offers long term support, allowing both foreign and domestic capacity investment; and
- An effective and an efficient mechanism for incentives.

In this respect, the Feed-in Tariff (FiT) mechanism has proven to be the best and the most effective mechanism, as verified by various international assessments.

Examples of Solar Market Drivers

A number of government programs have been implemented to accelerate the deployment of solar electric generation capacity. These programs include direct incentives for the installation of new solar electric generation capacity, renewable energy usage requirements (i.e., Renewable Portfolio Standards) and controls or limitations on pollution and/or emissions associated with conventional generation, including carbon emissions.

Available incentive structures for the deployment of solar power include:

- Investment Tax Credits, which reduce tax liability based on the cost of deploying solar assets (e.g., U.S.).
- Feed-in-tariffs, which require electric utilities to buy electricity generated from solar or other renewable sources at rates that are above the prevailing market rates (e.g., Italy).
- Production Tax Credits, which reduce tax liability on a per-kilowatt-hour basis for electricity generated by qualified solar energy resources (e.g., California).

In the U.S., there is a 30% federal investment tax credit (ITC) for commercial, industrial and utility solar energy systems, as well as five-year accelerated depreciation on solar assets. The U.S. federal ITC was recently extended to January 1, 2017. In addition, there are a number of state solar incentive programs, some of which are available for utility-scale solar installations.

- Italy: Targeting 16 GW solar capacity by 2016, with a minimum electricity price for renewable energy producers in addition to a feed-in tariff that scales by the size of the project
- Portugal: The country has substantial solar resources, imports 85% of its electricity and has a government targeting 50-60% renewable energy generation by 2020
- India: Supportive policies include a generation-based subsidy and a utility mandates to enter into long-term renewable energy PPAs
- France: Supportive policies include a recent reduction in the VAT for small solar systems, and a feed in tariff for solar projects
- South Korea: Recently enacted feed-in tariff is likely to be followed by renewable portfolio standards for utilities

Feed-in tariffs supportive of solar project developments are also available in Australia, Germany, Spain and several other countries.

3.2 Assessment of critical barriers for local PV market development and export oriented PV industry development in Armenia

Operation of the existing energy infrastructure should support the development of a more energy intensive economy in the upcoming years. This imposes challenges to the energy sector that suffer from the absence of domestic fossil fuel resources, dependency from imported fuel, non-diversified supplies, and luck of investments for the sector modernization.

In June 2005 the government of Armenia adopted Energy Sector Development Strategy. The strategy foresees diversification of fuel supply and generation. According to this strategy the generation of electricity will be based on nuclear power plant, new thermal power units at Hrazdan and Yerevan power plants, hydro power as well as renewable energy sources (small hydro and wind). The overall generation in 2025 is foreseen at about 10 billion kWh/year.

Legislation in Armenia provides that the country should develop domestic energy sources, particularly renewable energy sources (RES).Generally the development of RES mostly deals with the regulatory framework. Under the Law of the Republic of Armenia on the Regulation Body for Public Services the regulation in energy sector is carried out by the Public Service Regulatory Commission of the Republic of Armenia who is responsible for setting tariffs, issuing licenses and monitoring of the operation of the sector entities. Plants operating on renewable energy sources and generating electricity, benefit from privileged tariff regimes that are higher than the average generation tariff within the energy system.

No solar energy tariff exists in Armenia at this time except for those PV plants, up to 150kWp capacity, that operate under a “net-metering” concept. For the latter, there is no tariff set but the owner can benefit from “feeding” the excess of power to the grid and getting the same amount back at no cost. The current regulation does require permits and licensing for all grid-connected installations.

However, the major barriers that hamper development of PV industry are associated with investment risks that include an underdeveloped local market, subsidized power, limited access to regional markets, and currency risks.

Lack of state support. Although the Energy Saving and Renewable Energy Law of Armenia emphasizes the importance of renewable energy development in Armenia there are no incentive packages instituted to promote renewables in Armenia (for example tax privileges, state subsidies, or mandatory requirements and standards).

Difficulties in project funding. The local banks are not familiar with the renewable energy sector except a few that cannot afford offering significant soft term loans. Unfortunately, in a similar manner, the investors in the solar business in Armenia could not benefit from any commercial incentives, including state grants. For example, most projects in solar thermal business or other off-grid renewable energy projects in Armenia have been funded through international donor organizations at social and state owned sites. At present the program to offer soft commercial loans, are negotiated by the government with international donor organizations (World Bank, European Bank for Reconstruction and Development, etc.). To this end the R2E2Fund was established in 2006 to mobilize funding and operate revolving financing for renewable technologies. Currently, the fund is financing small hydro projects mostly by offering 5-7 year loans, up to 70% of the capital costs, charging up to a12% annual interest rate. A few commercial banks offer leasing mechanisms that, at present apply mostly to agricultural equipment, while many banks offer credits for household equipment none of which apply to solar energy systems.

VAT issues. Another problem is mandatory requirement to pay 20% VAT on the boarder along with 10% customs fees for equipment and machinery. Most of electronic components will be required to pass standardization procedure at National Standards Institute.

Transportation. Transportation has certain limitations, and presently large cargo containers to Armenia are shipped from Georgian Black Sea ports or Iran. Usually it can take up to four-five weeks to deliver a container from Europe to Armenia.

Investment Risks. There are risks associated with unpredictable foreign currency exchange rates (rates are regulated by the Central Bank). This poses uncertainty for an export oriented industry.

On the other hand, foreign investors can benefit from the same investment regime as it applies to local investors and can are treated in a similar manner. Regardless of its small size, the Armenian market is open for new market entries, and can be considered as a platform for market expansion to Georgia, Iran, Central Asia, etc.

3.3 Recommendations to overcome the obstacles that would hamper PV industry development in Armenia

The economic feasibility of solar energy projects in Armenia do not seem viable at this stage. Despite the Energy Saving and Renewable Energy Law that considers renewable energy development a priority in Armenia, there are no incentives and promotion mechanism that can attract investments in this field. First, the Armenia’s government plans to develop and refurbish the gas sector and build a new nuclear power plant (no externality costs are incorporated though). Second, the state budget carries deficits and is constrained to put emphasis on other priority areas such as social services, infrastructure development , etc. All these do not offer optimism for relying on government support at present.

One of the key motivators for utilizing solar energy for Armenia is the ideal insolation levels in throughout the country. Another attractive factor is the existence of raw materials and infrastructure to set up industry that can include the whole technological chain.

The investments in solar energy in Armenia can be boosted if the following are implemented: (i) sound government incentives, (ii) mandatory requirement by law, for using solar energy components where they are technically feasible, (iii) significant product cost reduction, (iv) attractive tariff for grid-connected applications, (v) simplified licensing procedures.

The SWOT analysis that has been made in Section 2 of this Report lists opportunities Armenia can take to develop a PV industry. At the same time, a strategy to handle problems related to potential threats could be as follows:

-promoting and lobbying activities for favorable regulative and incentive structure
-market development locally and regionally
-public awareness campaign
-knowledge transfer and utilization of corresponding technologies
-capacity building and educational programs
-product cost reduction
-cooperation with banks to develop retail schemes
-source out cheap money for commercial projects

Of those above mentioned items the most critical elements for a PV industry development in Armenia should be attractive tariffs and state incentives .

LOCAL MARKET DEVELOPMENT	EXPORT MARKET ORIENTED INDUSTRY DEVELOPMENT
Attractive tariff (grid-connected plants) Mandatory standards (off-grid applications) Retail financing schemes by commercial banks (off-grid applications)	State incentives (industry and associated sectors)

Tariff for solar energy. Based on the study under EU/TACIS/DEM project (*“Renewable Energy Economic Potential of Gegharkunik marz” Vol.II. Feasibility study report, Nov 2007*) the economic cost of electricity production by small-size grid-connected PV plant (less than 100kW) was calculated at about EUR 0.60/kWh. The tariff required for larger grid-connected installations could be slightly lower, but still an investor should expect attractive ROI in order to invest in PV plant development. The development of a PV industry locally, on the other hand, could result in the reduction in the cost of grid-connected PV plant project generated through the more competitive price of PV modules.

Mandatory standards (or RPS). The state should come up with incentives to promote PV technologies development through setting mandatory provisions. For example in Construction Codes include the requirement that any new building project should have certain percentage of electricity generation through the use of PV, Others could include PV powered facilities in national parks and environmentally vulnerable areas. Another promotional tool can be mandating the utilities to include a minmum percentage of renewable energy generation in its portfolio, etc.

Retail financing. The state should come up with initiatives for commercial banks to offer attractive retail financing for off-grid applications.

State incentives in tax policy. Finally, the state should offer attractive conditions for PV industry development, such as VAT-paid-on-boarder waiver for technological machinery, profit tax privileges for the PV industry, tax holidays, etc. More emphasis should be on FOREX policy to support a local export oriented industry.

4. CONCLUSION

Solar electric systems provide the opportunity, in cost effective ways to increase electric generation capacity while at the same time avoiding environmental degradation that inherent in the construction and commissioning of conventional electric power plants. Solar power generation industry has the potential for substantial growth. Recall, the future solar market is estimated to be at least 30 GW annually in 2020**.**

Under current market conditions development of solar energy in Armenia seems problematic because of the need for high up-front capital costs and subsidized electricity costs from natural gas and nuclear power plants. Assistance from international organizations and the government is needed to improve the legislative environment that can promote the solar energy technologies and PV industry development. Another important step is product cost reduction and developing both local and regional markets. If all these are done the, development of PV industry based on local raw materials can become economically viable.

Main findings of this study are the following:

a) Armenia possesses a significant solar energy potential. There are 2500 sunny hours per year and the average annual insolation on horizontal surface is about 1720 kWh/m^2.
b) Solar energy development at present is in Armenia is in its infancy.
c) During the past ten years, the economic development of Armenia has been significant due to state policies economic reforms, substantial financial , capital growth, the development of various industry sector, and liberalization processes.

d) At present, the energy prices in Armenia are low compared to the international market, because of low natural gas prices and electricity tariffs. Residential areas,, services and industry all have access to electric power. In fact, Armenia can be counted among the best in the world for having a grid system that covers the whole country..
e) The government of Armenia emphasizes the priority of renewable energy development in the country at both regulative and legislative levels. However, there are no real promotional mechanisms that can stimulate the new sector development. At the same time, foreign investors are encouraged to enter the local market and are treated as equals with local companies.
f) Having the government support in promoting solar technologies, it will be possible to develop a solar PV market locally as well as to develop PV industry for export markets.

Success in the market penetration depends on a competitive pricing, quality, durability, reliability, fast deliver, additional benefits for the end-users, barriers that exist to be removed. Armenia offers an excellent location for manufacturing of PV products for a number of reasons - politically stable, emerging economy, excellent access to raw material (high quality sand or also silica), lower cost labour, low cost electricity, land is plenty and cheap available, and many other supportive factors. However, one must recognize the disadvantages with the land-locked location and difficult access to the main markets.

Although various market strategy would offer different value chain, the strategy to develop PV modules as a final product from A to Z of the technological chain (while the modules production will be based on Poly-Si/UMG blended chain) could offer to the industry flexibility in supplying other "chain" products whenever they are competitive.

Key to successful for export oriented PV industry development as well as local market development in Armenia depends on both favorable regulative and legislative framework such as: attractive tariff, mandatory standards or RPS, state incentives and tax privileges.