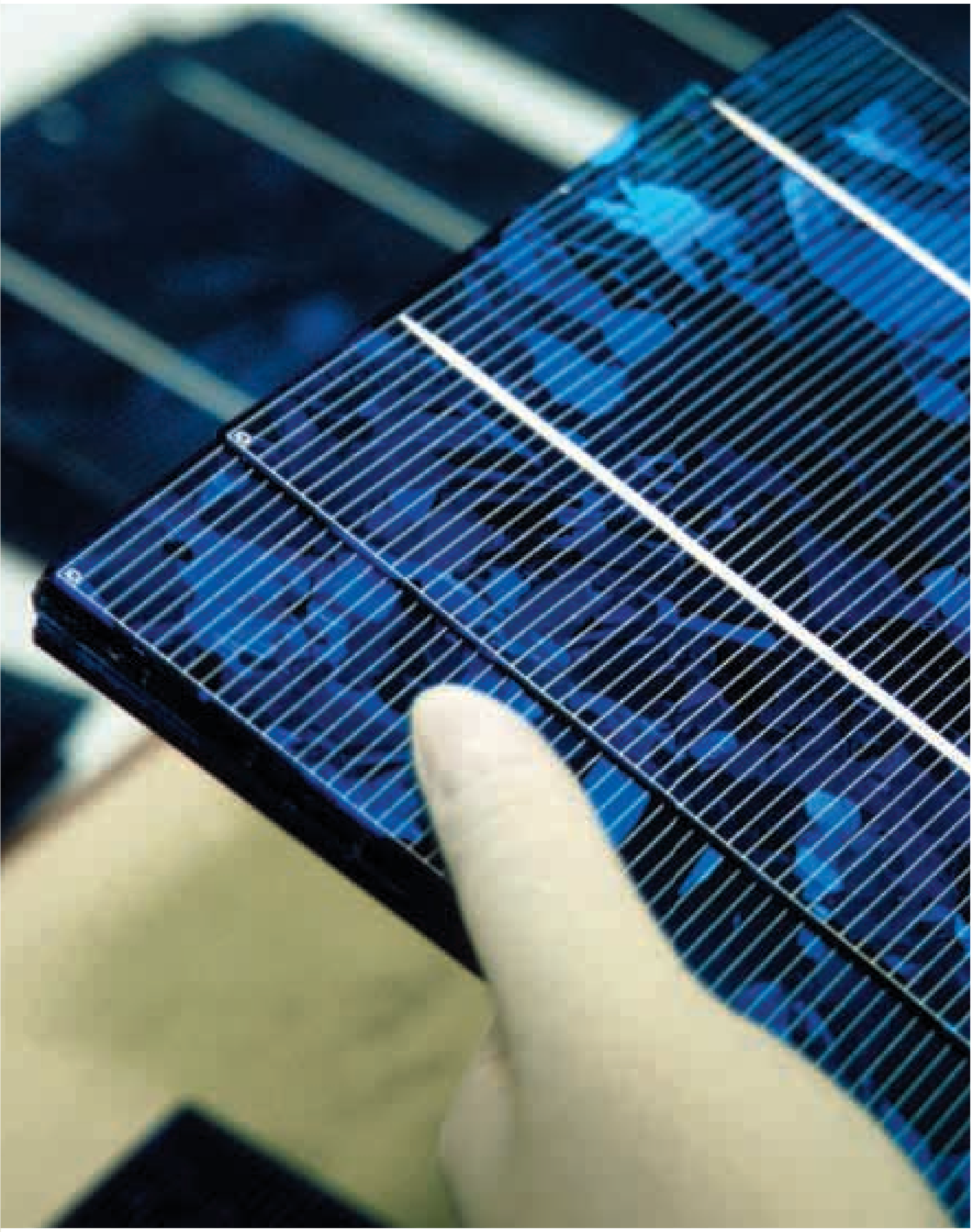
European Photovoltaic Industry Association



EPIA ROADMAP

EUROPEAN PHOTOVOLTAIC INDUSTRY ASSOCIATION

FOREWORD

The favourable conditions created recently by the White Paper and the RES Directive will help Photovoltaic (PV) Solar Electricity to accelerate its pace in becoming a major contributor to world-wide electricity generation. Indeed, European Union (EU) Member States following the lead of the European Commission, have set a target of a 22 % contribution of renewable energy sources to electricity in the EU by 2010.

In order to achieve this objective and obtain a sustainable energy scenario in the EU, emission-free, high-tech and universally applicable solar electricity systems need to be installed rapidly.

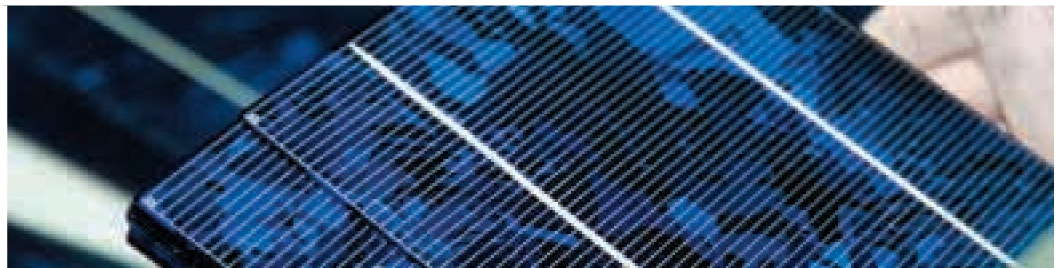
The European Photovoltaic Industry Association (EPIA) Roadmap presents the European PV Industry priorities for achieving this objective. It includes quantified goals, consequent incentive policies and the necessary development of technologies.

EPIA has devised a programme of specific actions that European industry in collaboration with other key stakeholders from research, policy, finance, electricity industry, the construction industry and other sectors should adopt in order that Europe will capitalise on the global PV market potential.

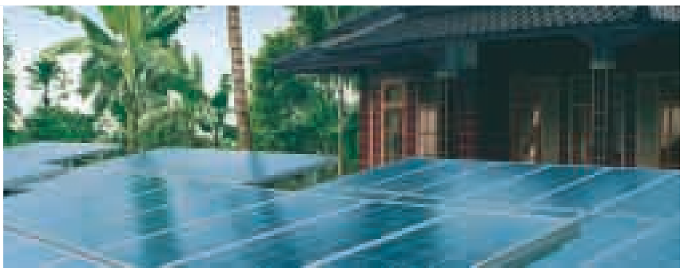
This EPIA Roadmap highlights the key obstacles and issues that must be resolved to enable PV to contribute substantially to both the European and global energy supply. It is intended to serve as a guide for European industry and research to 2010 and beyond, and as a framework of political action to help realise solar electricity's fast potential to become the major contributor to electricity generation in this century. The Roadmap will be updated regularly to reflect the prevailing situation of the industry and markets in Europe and worldwide.

Winfried Hoffmann
President of EPIA
Chairman of the Managing Board of RWE Schott Solar GmbH

TABLE OF CONTENTS







1 EXECUTIVE SUMMARY

1.1 INTRODUCTION

It is generally accepted by society and actively encouraged by governmental bodies that electricity generation from renewable sources needs to become one of the essential contributors to the energy mix. There are indeed many options to use renewable energies but photovoltaic electricity generation from solar radiation has a uniquely strong and most valuable position.

Solar cells, the basic elements of photovoltaics (PV), convert light energy directly into electric energy. This one-step process is clean and absolutely emission-free; it is a modular electricity source that can be installed in every power size from microwatt to multimegawatt scales of. Therefore, it is ideally suited for distributed generation of electricity near the user, everywhere around the globe.

PV solar electricity together with solar thermal has the highest potential of all renewable energies since solar energy is a practically unlimited resource available everywhere. All energy scenarios worked out during recent years agree that solar electricity will play a major role in the energy mix within the next decades.

Photovoltaics will be one of the key energy technologies of this century, and its extensive industrial development must be accelerated now.

To make PV a success, a concerted action of industry, government, research community, and society is mandatory. This development has already started in some countries, Germany and Japan being amongst the very first. The Japanese Government paved the way for innovative legislation and a substantial financial effort. In cooperation with the PV industry, the building industry, utilities, and many regional and municipally governments, a substantial market growth in Japan has been initiated. The result is apparent, with Japan being the largest world market and having the strongest PV industry.

In the European Union, Germany has shown that through supportive legislation the market growth can be stimulated considerably, and Germany is being now the second strongest market worldwide.

The European PV industry, which is growing rapidly, is willing to strengthen the European efforts on sustainable solar electricity by increasing its commitment in market, research and industry development considerably:

The European PV industry is committed and in a good position to play a substantial role in the rapidly growing world market of photovoltaic components and systems.

1.2 THE EPIA ROADMAP

This document

Roadmap of the European Photovoltaic Industry Association (EPIA)

emphasises the importance of the task mentioned above, demonstrates the challenges, and describes routes to success. It summarises the results of intensive discussions within EPIA and with outside experts.

This document is intended to

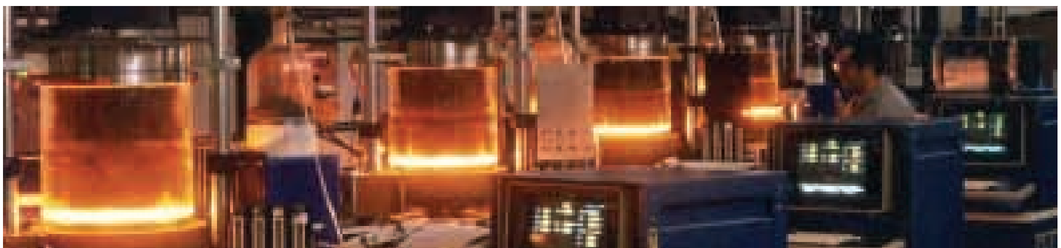
- analyse the situation and make realistic projections to the future
- identify hurdles and deficits in the development of technology, industry and market
- define goals for fast progress in all fields and outline concepts for achieving the goals
- define and realise targets and milestones to direct the effort
- help to form industrial partnerships to carry out the different tasks involved.

A large number of benefits will result from a success of the efforts described in this document, such as:

- A push forward for the improvement of technology and the reduction of costs
- Growth of an innovative and sustainable industry to maturity, comparable and even higher in size to the semiconductor industry
- Creation of investment opportunities and jobs.

Accomplishing the tasks defined will make photovoltaics competitive with conventional energy within the next two decades putting Europe in the forefront of clean power generation.

During recent years the European PV industry has developed very successfully. All branches of PV manufacturing, distribution and system installation are represented by strong companies, and their global market share is rising steadily. Technology development and research are on a high level, and the industry is in an excellent position regarding the challenges of the future. This Roadmap is designed to be an effective tool to maintaining, exploiting and strengthening European leadership in the PV sector.

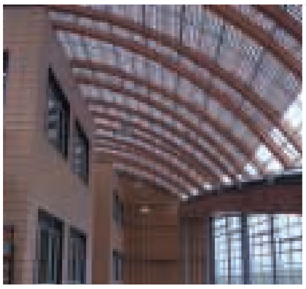


1.3 THE STATUS OF PV SOLAR ELECTRICITY

1.3.1 GENERAL

Terrestrial use of PV solar electricity started around 1980, and since these early efforts photovoltaics have developed very steadily in terms of technology, industry, and market share:

- **Technology**: Cost of first solar cells was high and efficiencies relatively low around 10%. The price went down by a factor of ten during the past twenty years and efficiencies today are between 14 to 16%. Reliable products are on the market, and modules are generally sold with guaranteed performance of 20 years and more.
- **Industry**: In the mid-nineties companies started to invest in commercial production plants, and nowadays mass production is rising due to the development of adequate equipment and technologies. More than 30 companies are delivering PV cells and modules worldwide with the first five serving more than 70 % of the world market, and the competition is strong. Since 1999 the Japanese industry has the largest market share worldwide.
- **Market**: PV markets developed differently in the various application sectors and in different geographic regions. The growth rate was about 15% per year until 1996, and since then the rate was always well above 30 % per annum (p.a.).



1.3.2 TECHNOLOGY AND MANUFACTURE OF PV MODULES

First solar cells were made from semiconductor silicon, and this technology is still alive. Crystalline silicon solar cells in their different forms - monocrystalline (Cz-Si), multicrystalline (mc-Si), ribbon – have a market share of more than 90%. The rest is provided by thin film technology, mainly amorphous silicon (a-Si).

All crystalline silicon technologies rely on the supply of wafers, silicon sheets of the thickness of about one third of a millimetre. The cost of the wafer is a substantial part of the total cost of solar cells. As such, cost reduction of wafer production is a real challenge for the industry.

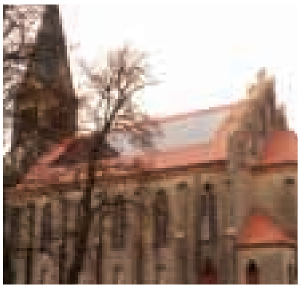
Solar cells are connected by metallic leads to deliver the right output voltage and current, and they are encapsulated in polymers behind glass to protect them from the environment. The resulting sandwiched plate is called a PV solar module, and this is the true PV product for the customer.

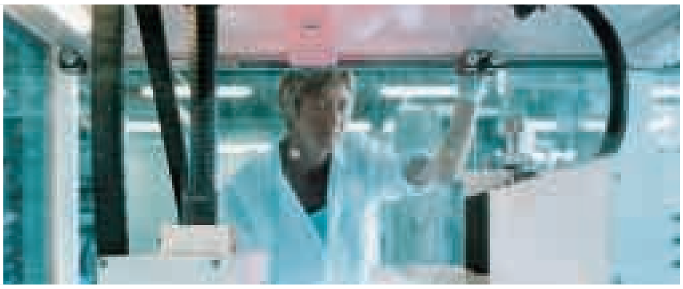
In case of the crystalline silicon technology large scale production is already common, and the equipment industry is now able to deliver complete production lines. The thin film technologies are still in the pilot stage since industry only slowly starts to invest in larger-scale plants, and one of the major challenges is the need for efficient equipment for mass production.

Cost of production needs to be reduced considerably to penetrate the major electricity markets. Consequently, the main effort of research and industrial technology development is directed towards reducing the production cost. Since materials cost is a substantial part of the total cost, reduction of materials consumption is essential, especially in the case of crystalline silicon. Since the selling price of modules is determined by the price per unit of peak power delivered by the module (/Wp), efficiency enhancement of the solar cell also reduces the specific materials consumption.

In the course of the analysis a number of research and development items have been identified. These are described below under the heading 1.4 Strategic Action Plan. It has become clear that many of the defined tasks are best solved in a concerted action of the PV industry with partners from the research community, either research institutes or universities, and with partners from other industries. Important partnerships could be established in the following areas:

- ***Si materials development***: Silicon producers with solar cell producers
- ***Silicon wafer***: Crystal grower and wafering companies with equipment makers (wire saw, etc.)
- ***Si solar cell manufacture***: Solar cell producer with research institutes and equipment manufacturer
- ***Module fabrication***: Module makers with glass industry, chemical industry (polymer chemistry), equipment manufacturer





- ***Thin-film production***: Cell/module producer with research institutes and equipment producer (e.g. vacuum and deposition technology).

These are only a few examples to show where cooperation in different technology areas will determine the strategy for faster progress.

1.3.3 SYSTEMS AND COMPONENTS

In most developed countries in which PV systems are connected to the local electricity grid, in order to provide consumers with electric power from a PV system it is necessary to optimise the delivered power and to convert direct current (DC) into alternating current (AC). In many systems a storage medium such as batteries are employed as well. This is particularly the case in developing countries and remote areas of industrialised countries, in which case the final power is delivered via direct current. These latter systems are referred to as stand-alone systems. The power conditioning equipment represents a major part of the PV system technology.

Two electronic devices are predominant in PV Systems, the charge controller in the stand-alone systems with batteries, and the inverter to generate AC from DC. Charge controllers are responsible for the long life of the battery. Since the battery is an expensive part of the system, high quality charge controllers are needed. Nevertheless, the life of batteries in PV systems is limited, and their replacement is the main reason for the high lifecycle cost of stand-alone systems. Improved batteries will be a real benefit for the PV installers, and additional efforts in their development will benefit the business in remote areas as well as for grid connected systems.

The inverter has to fulfil even higher expectations. Its common use is in grid-connected systems, and three properties are essential: high conversion efficiency, extremely long life, and meeting of the safety requirements of the utility. The quality of the inverter must fit to the highest industrial standard, while on the hand the price of the device should be reasonable. Due to extreme effort of the industry, the quality of inverters has improved considerably in recent years, and the large number of existing reliable systems installed helps the industry to become profitable.

European producers of system components have been the leading companies in terms of development and production.

EPIA sees system technology expanding dynamically into all areas where customers need electric power, competing already successfully with conventional power in rural areas and reaching grid competitiveness in the next decades.

1.3.4 APPLICATIONS AND MARKETS

The main applications of photovoltaic electricity generation can be grossly divided into four categories:

- Grid-connected systems 71% market share in 2002
- Off-grid industrial applications 15%
- Rural electrification in developing countries 7%
- Consumer applications 7%

Currently, the market is dominated by **grid-connected systems**, since this segment is supported in some countries, with Japan and Germany having the largest share. These are mainly residential rooftop systems, but during the last three years a growing number of larger systems between 100 kW and a few MW power have been installed on public and industrial buildings and on the ground. A small but

high value application is the building integrated PV (BIPV), special PV modules used for façades, roofs, and shadowing elements.

The **off-grid industrial market** represents the applications where PV is already cost competitive compared with other techniques of electricity generation. The stand-alone generators are used to provide electricity for telecommunication, telemetry, traffic signs, corrosion prevention, water desalination, and similar applications.

Rural electrification in developing countries represents a major market and an opportunity for improving living conditions of approximately 2 million people living in those countries who currently do not have access to electricity, by providing light, water, communication, and health care. The technology for this application is available, and with major efforts to develop infrastructure and establishing affordable end-user financing schemes this market segment could exceed grid connected markets. Furthermore, it would allow developing countries to establish modern decentralised systems superior to those in the industrialised countries.

The **consumer market** implies a wide variety of applications from substitution of batteries in small devices to the electrification of recreational vehicles and sailing boats. It is a constantly growing sustainable market.

Altogether, the PV industry was able to sell PV modules of a power of about 700 MWp worldwide in 2003, and EPIA expects that the shipments will rise to over 1 GWp just in a few years, with a growth rate well above 25%/year. At the same time, larger production units will lead to substantial cost reductions.

Worldwide the solar electricity industry already provides employment for over 35,000 people. The opening of new PV production facilities can result in about 20 jobs per MWp of capacity, with additional jobs in the wholesale, retail, installation and maintenance services providing about another 30 per MW of installed capacity. These jobs are mostly located on a regional level near to the final customer.

1.4 STRATEGIC ACTION PLAN

1.4.1 BASIC PROGRAMME

EPIA has devised a programme of specific actions that European industry, in collaboration with other key stakeholders from policy, finance, electricity industry, academia, the construction industry and other sectors should adopt in order that Europe may capitalise on the global PV market potential. Central to the programme are the following three branches of policy support which provide the long-term stable platform for industry to base its investments upon:

- **A European rate-based incentive scheme (feed-in tariff)**. Using the German model to stimulate grid-connected PV, there should be a guaranteed price paid through utilities for PV generated electricity of x Euro/kWh, guaranteed for y subsequent years. x and y should be chosen in such a way as to allow to operate the system economically (e.g. in Germany x = 0,57 Euro/kWh and y = 20 years). During the lifetime of the incentive scheme the guaranteed feed-in tariff could fall each year for new contracts, in order to encourage PV manufacturers to strive for continued cost reductions. To keep this scheme simple and effective from an administrative point of view every electricity consumer will pay a small surcharge with his electricity bill to the utility company.

- ***Continued focused RTD Programme with improved funding arrangements***: Extensive research and technological development is essential for the European PV industry to remain competitive and to open up new markets. The major goal of all efforts must be substantial cost reduction for all steps of the value chain, from materials to systems, in order to eventually compete with other techniques of electricity generation. Intense co-operation between the research sector and industry is required to reach that target.

- **Export promotions assistance**. To promote exports of European technology, particularly to the rural electrification market in developing countries. The encouragement of partnerships between European industry and companies in developing countries for product development for this special market is essential. Furthermore, assistance in the introduction of revolving fund schemes should be given to foster the market for rural PV systems.

1.4.2 TARGETS AND MILESTONES FOR EPIA ROADMAP

Very detailed targets and milestones have been elaborated for the areas Technology, Systems and Applications, and Market Development. These are described in Chapters 4 to 7. Basic findings can be summarised as follows:

- **Technology**: Reduction of production cost remains the key target of all technology development, but the guarantee of the availability of all materials and components is of similar importance. In the field of materials, the availability of economically priced high-purity silicon as feedstock material is of crucial importance and needs special support. In all steps of the silicon technology, from crystallisation to solar cell production, reduction of material consumption and improvement of efficiencies are to be carried out. In thin-film technologies, the step towards cost effective mass production has to be done, which includes the development of the required equipment. In module fabrication new technologies and designs are needed to realise substantial cost reductions. Module life has to be extended to 35 years and beyond.

- ***Systems and Applications***: For electronic components substantial cost reductions will result from larger production quantities. The operation time of these devices should be extended to the lifetime of modules. Standardisation of components and systems is important for mass production. Special attention must be paid to the development of stand-alone systems which will play an increasing role in the electrification of remote areas in the developing world. In the utility area two efforts are of importance: Concentrating systems using highest efficiency solar cells will become an interesting opportunity for large installations in southern countries, and in areas with high penetration of distributed installations, management of the grid will require special attention.

- **Market Development**: The many different types of markets have to be developed. Major attention should be paid to the two biggest market segments, the grid-connected systems in

industrialised countries, and the stand-alone installations in remote applications in developing countries. The grid-connected market needs special funding arrangements and regulations to ensure the connection to the grid, whereas the market in developing countries needs the build-up of a business infrastructure and the introduction of adapted financing schemes. The expected cost reduction of systems will make photovoltaics competitive, and the markets will become self-regulating.

- **Industry**: The European PV industry is in a good position when compared to its international competitors. All steps of the value chain, from the starting silicon material to the finished modules and the systems, can all be covered by companies of European origin. However, in order to boost European Industry and avoid unfair competitive conditions, EPIA proposes that the major portion of systems installed under a feed-in scheme to be of European origin.

1.5 CONCLUSIONS

A substantial part of the future energy supply will be delivered by renewable energies, and a major role in the field will be taken over by photovoltaic electricity generation.

The European PV industry is committed to play a leading role in the fast developing market. This EPIA Roadmap provides guidelines for this development and sets targets and milestones for the partners engaged in this effort. Strong effort in technology development, investments in production facilities and market expansion through political support will be required to keep this technology in Europe and to create jobs and opportunities.

In summary, this EPIA Roadmap will become a guide for industrial development, PV research, political support mechanisms and world-wide market development to strengthen Europe's position in one of the key technologies of this century.

2.1 PHOTOVOLTAICS – THE BEST CHOICE

Photovoltaic solar electric generation technology is one of the best means to provide electricity in a clean manner virtually everywhere around the globe. PV is a modular solid-state power generation system, producing electricity directly and solely from sunlight. It can be installed in small and large scale systems, and it does not give rise to emissions harmful to health or climate or any other dangerous by-products. The raw material for the vast majority of current PV production is silicon – the second most abundant element on earth. Solar modules are also net producers of energy, typically generating between 5 and 12 times more energy over their lifetime than is required for their manufacture, depending on technology type and amount of sunlight available at the location of installation.

PV is virtually unique as an energy technology in that it can be deployed very rapidly in both rural and urban environments. A single PV module (typically rated at 120 watts power output, equivalent 1 m^2), together with a suitable battery can be installed in a very short time and will provide enough power for several compact fluorescent lights and a radio or TV for in the order of four to five hours a day. This can be truly life-changing for a family in rural Africa, Asia or Latin America. Connecting a number of these same basic modules together provides more power; a system equivalent to 20 m^2 of such modules together with appropriate power conditioning equipment could over the course of a year meet about half the annual electricity requirement of a typical north-European household. Literally any power requirement from a few watts to, conceivably, gigawatts (GW_p) of power can be achieved simply by connecting more modules together. Because there are no moving parts maintenance requirements are minimal and good modules can reasonably be expected to continue generating at 90% or more of their rated power for 25 years or longer.

PV is much more than a simple electrical generator. Amongst other values, it is an elegant construction material that can be used to enhance the architectural character of buildings or other urban structures, such as sound barriers and bus shelters. It can provide weatherproofing, shading, sound-proofing and enhanced thermal functions for buildings.

To summarise: PV electricity generation has a lot of benefits which makes it unique amongst the other sources of electric energy. It is ideally suited for distributed generation of electricity near the user, everywhere around the globe. What seems to be most important in the long run is the fact that PV has the highest potential of all renewables, according to many scientific studies.

The technology is sound, the need and opportunity are evident, but PV currently meets only a small part of global electricity demand. So what is preventing more widespread adoption of PV to help meet our growing energy demand in an environmentally sustainable way?

This document prepared by the European Photovoltaic Industry Association (EPIA) highlights the key obstacles and issues that must be resolved to enable PV to contribute more significantly to European and broader global energy supply. It is intended to serve as a roadmap for European Industry and technological development to 2010 and beyond, and as a framework for political action to create a flourishing and viable industry and market.

2.2 A BRIEF HISTORY OF PV MANUFACTURING AND MARKET DEVELOPMENT

PV solar electricity is a booming industry; since 1980 when terrestrial PV applications began in earnest, annual production of solar generation equipment worldwide has increased virtually a hundred-fold to an estimated 700 megawatt (MW_p) in 2003. The industry is today worth in the order of €3.5 billion per annum – a figure which is increasing at a rate of more than 30% per money wise at the current time.

Until 1997 the manufacturing industry was growing at between 10 and 15% per annum, but since then a series of government support programmes in OECD countries aimed at assisting end-user purchases of PV systems, particularly in the residential sector, have resulted in explosive growth. The period 1997-2003 saw the market grow consistently above 25% each year, and on average by more than 35% power related passed the 200 MW by the end of 2003 the cumulative installed capacity of all PV systems around the world had reached 1300 MWp of which approximately 20 % was located in Europe.

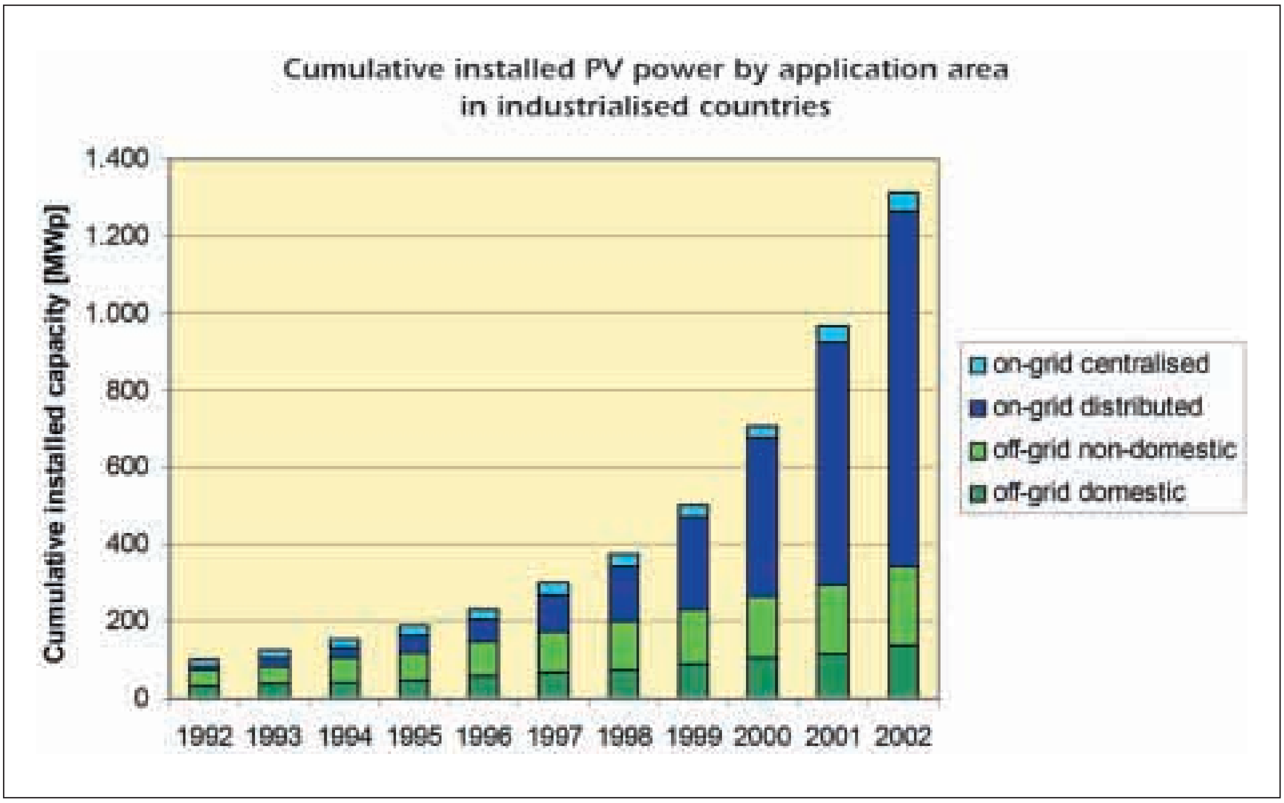


Fig. 1: Cumulative installed capacity by application (Source: IEA PVPS)

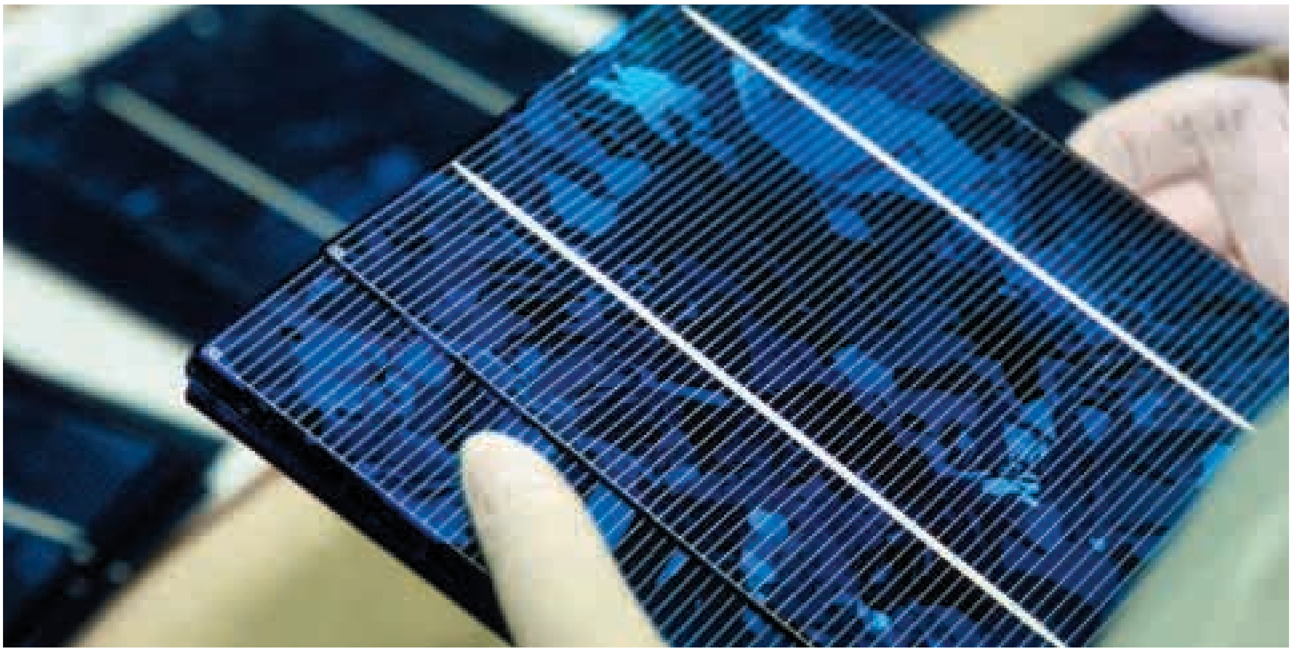
2 INTRODUCTION

Worldwide the solar electricity industry already provides employment for over 35 000 people. The opening of new PV production facilities can result in about 20 jobs per MW of capacity, with additional jobs in the wholesale, retail, installation and maintenance services providing another 30 per MW of installed capacity. These jobs are mostly located on a regional level near to the final customer.

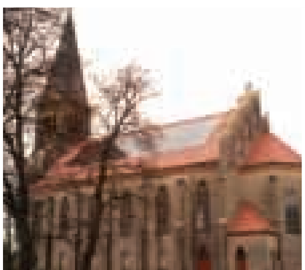
The main application segments for PV are remote industrial (e.g. off-grid telecommunication repeater stations), consumer applications (e.g. PV for car sunroofs), developing country applications (mostly off-grid solar home systems) and grid connected systems. Historically the main market segments for PV were the remote industrial and developing country applications where PV power over the long-term is often more cost-effective than alternative power options such as diesel generators or mains grid extension. Worldwide, the cumulative share of off-grid to grid-connected applications is approximately 40:60 at the present time.

According to the findings of the International Energy Agency's PV Power Systems programme, since 1997 the proportion of new grid-connected PV installed in the countries participating in the programme – most of the main OECD nations[1] - rose from 58% to over 86% in 2002. This equates to approximately 61% of the total additional capacity installed worldwide during the year if it is considered that all installations outside the reporting countries are off-grid.

The EU (particularly Germany) and Japan have also been the main players in the fostering of more positive legal frameworks to enable grid connection of PV systems. The increasing strength of these markets will help to create a secure and sustainable base for the PV industry.



[1] List PVPS Member countries



2.3 PHOTOVOLTAICS – POWERING OUR FUTURE

EPIA believes that PV represents a major building block for a sustainable electricity future. Without the development of PV, replacing fossil electricity generation, a long-term energy scenario will be incomplete. Whether the European industry will be able to participate in this future key technology is a matter of implementing such actions as described in this roadmap.

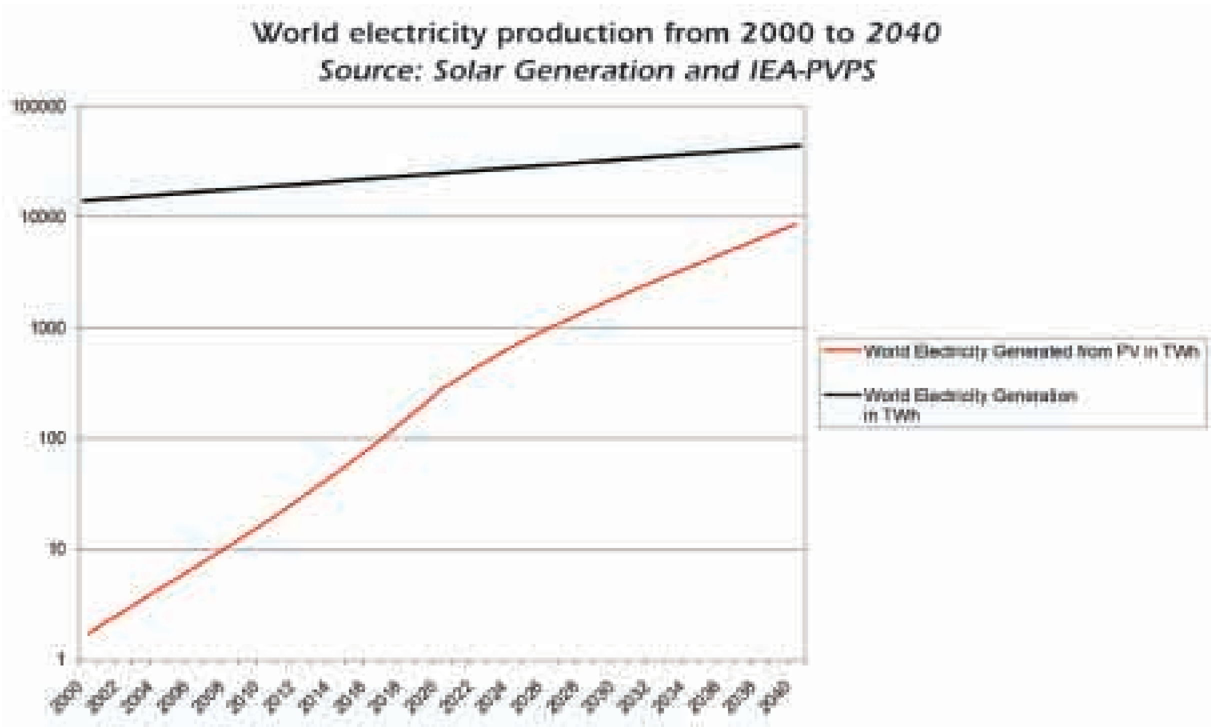
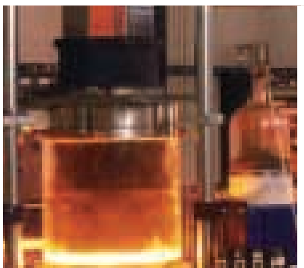


Fig. 2: Contribution of PV solar electricity to global electricity production

One obvious question is what will be the impact for Europe if it does not respond to the PV challenge? Arguably in the short to medium term and even up to 2020 the impact would be small; Europe will not suffer power shortages in this timeframe as a result of failing to invest in PV. Fossil fuel usage over the next twenty years is still predicted to rise and will dwarf even the most ambitious PV contribution. Nuclear fission options are unlikely to be revived due to adverse public opinion, while fusion remains largely an expensive pipe-dream, but other renewable technologies, particularly wind power, which are closer to providing economic bulk power, would continue to be adopted to address near-term climate change commitments.

The real impact only becomes clear in the long term. Fossil fuel availability will eventually decline and viable, sustainable energy alternatives must be available to bridge the gap. Wind power again is expected to provide the lion's share, but current estimates limit the available European resource to little



over 20% of OECD-Europe 2020 electricity demand[2]. Hydropower, biomass energy and the ocean technologies also have a role to play, though each is limited by reasonably accessible resource. Solar PV electricity, with its unique suitability for urban application has no such resource limitations. Moreover the resource is ubiquitous. PV represents a common sense solution towards future electricity demands.

It is also important to appreciate that PV market development is not only dependent upon how the EU chooses to address the various technological issues or its response to the market needs and opportunities. Even if the EU continues with a business as usual policy, it is quite possible, indeed highly likely, that PV will eventually become competitive with bulk electricity prices through initiatives in Japan, USA and Australia, and measures aimed at improving energy services in Developing Countries. This raises the question - "why should the EU bother?" EPIA is convinced that if the Europe fails to adopt a proactive stance towards PV market development valuable business opportunities will be lost. From a strong position in 1995, where it accounted for a third of worldwide manufacturing, Europe then lost considerable market share to USA and Japan.

Only recently given the stronger policy environment in Europe – particularly Germany – have manufacturers chosen to reinvest in European facilities. This is an important lesson; strong foreign industry offering good quality low-cost products could conceivably dominate the European market for this clean energy technology. This negates - at least until installed - the energy-autonomy which is an important benefit of PV and other renewable energies. European companies are called to play in a game of unfair competition and some times become difficult to compete in a global market level that means no job creation and added value for the european industry

This roadmap acknowledges that, if the EU is to take maximum advantage of the opportunities associated with PV market deployment, all parties - government, industry, financiers and user groups (Utilities, building developers, architects, local authorities) - must work towards common goals.

The EPIA roadmap recommendations are to be considered by each actor in the solar sector. Europe will suffer the loss of its current strong market position and potential major industry for the future. The PV industry can be of great importance to Europe in terms of wealth and employment, with 59 000 PV-related jobs in the EU in 2010 if the targets are met, and a figure of 100 000 jobs would be realistic if export opportunities are exploited.

Continued reliance on centralised electricity generation concentrates employment in specific locations, whereas PV employment is distributed on a local level, which fits in well with regional development goals.

The added values of PV must also be considered, from the social and economic benefits of rural electrification in agreement with EU International Development Objectives, to supply security and to the significant environmental benefits.

Is the European PV industry ready at this moment to react in the right way to these challenging opportunities? – The answer is "yes, indeed", for several reasons:

[2]WIND FORCE 12, A blueprint to achieve 12% of the world's electricity from wind power by 2020, EWEA and Greenpeace, 2001

- During recent years European PV industry experienced a rapid expansion of manufacturing capacity, due to favourable market conditions
- A well developed technology with a broad scientific background encourages investments
- More and more European equipment manufacturers offer professional production equipment or even turn-key factories
- Investors, and even utility companies, obviously believe in the long-term chances of PV solar electricity.

Figure 3 demonstrates the impressive growth of manufacturing capacity in Europe. It is apparent that production capacities of solar cells and modules are now exceeding the current size of the PV market in Europe. One conclusion is that for the European PV industry the development of additional home markets such as Spain, Italy, Greece, etc. and development of export markets becomes vital for further expansion.

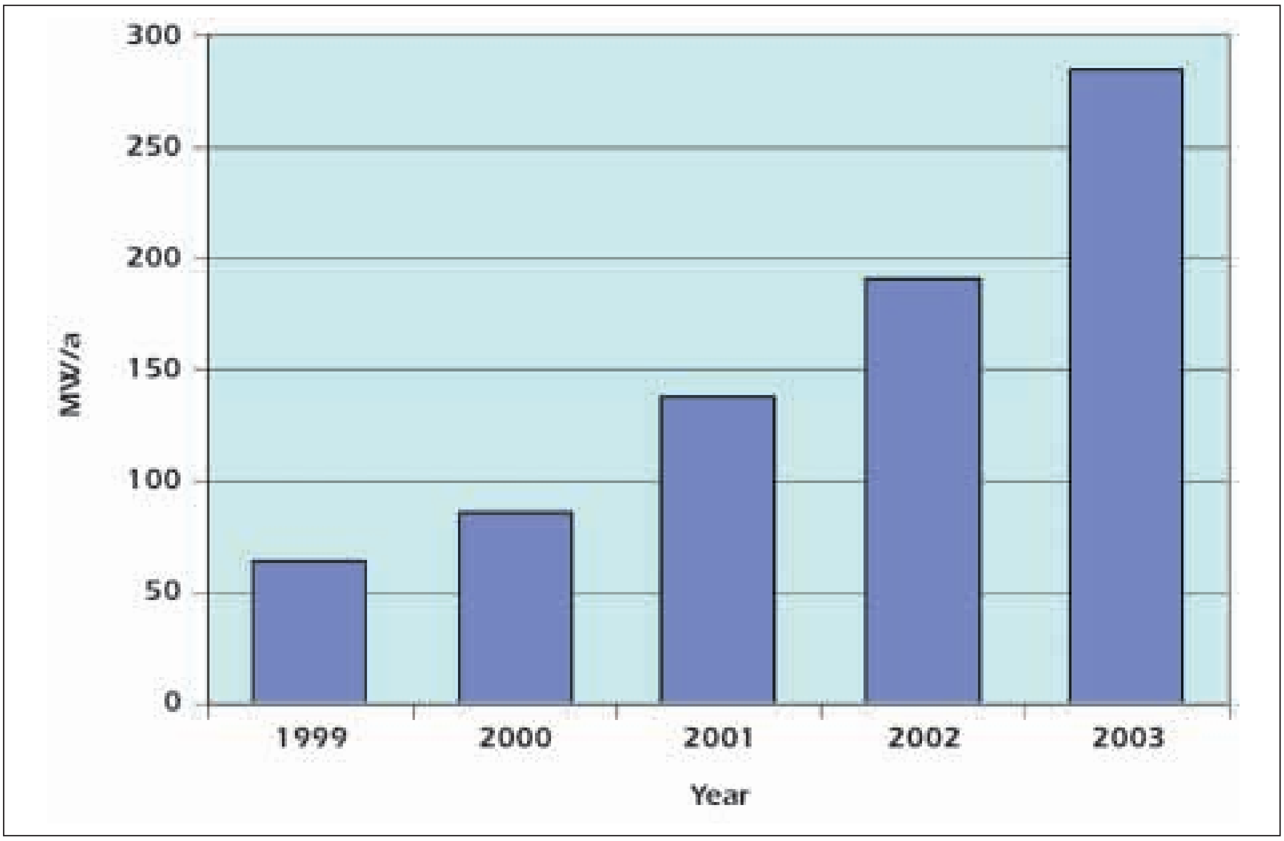
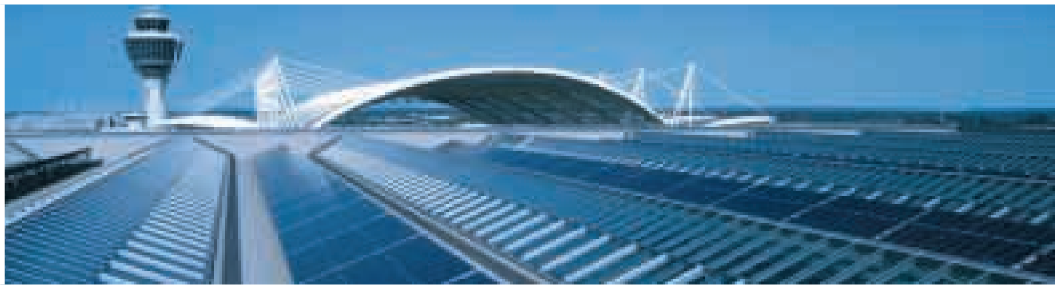


Fig. 3 Increase of solar cell production capacity in Europe (2003: preliminary data)
Source: Photon International

3 ROADMAP OBJECTIVES AND METHODOLOGY



3.1 GENERAL OBJECTIVES

The general objective of this effort is to identify the measures required to make PV industry and markets strong enough to play an essential role in the future electricity supply.

Today, photovoltaic electricity generation is still rather expensive and can compete only on special markets. Strong effort is needed to make PV compatible to other renewables on the bulk markets in industrialised countries.

The operation cost of PV systems is nearly negligible since maintenance costs are low, and fuel costs are zero, so the problem reduces to the high investment costs.

Main target of all efforts to develop photovoltaics must be to reduce investment costs of PV systems.

Appropriate measures are to improve technology, or even to look for new technology options, to develop mass fabrication techniques and the appropriate equipment, and to invest in scaled-up production units.

Photovoltaic electricity generation has numerous applications with different cost structures. Continuous cost reduction will step by step broaden the field of competitive markets. In many remote applications PV is economic even today. In the grid-connected markets, cost competitiveness will start in the peak electricity market. Accordingly, the second general objective will be to develop markets to expand the base of the PV business.

Second target of all efforts must be to develop markets, home markets by the introduction of funding schemes for investments, and export markets especially in remote areas of developing countries.

To make PV a success, a concerted action of government, society, industry, and research community is mandatory. This Roadmap of EPIA provides guidelines for this development and sets targets and milestones for the partners engaged in this effort.

3.2 METHODOLOGY

Five steps have to be executed for the planning process:

- ***Analysis of the situation*** and an acceptable **projection to the future**.
  Extrapolation of the market development beyond 2010 is certainly difficult since it depends so strongly on the political scene.

- **Identification of hurdles and deficits** in the development of technology, industry and market.
  Since PV is still a young industry a number of deficits can be recognised, but all are well defined.

- **Definition of goals** for fast progress in all fields and **outlining of concepts** for achieving the goals.
  Main challenges are in the field of production technology and in market development.

- ***Setting of targets and milestones*** to direct the effort.
  Targets for the technological development are widely discussed and agreed upon.

- ***Allocation of partners*** for the different tasks involved.
  To make PV a success, a concerted action of industry, the research community, government, and society is mandatory. Strategies for cooperative effort have to be worked out.

4 TECHNOLOGY DEVELOPMENT

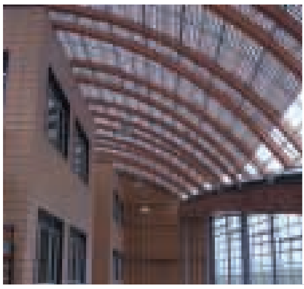
4.1 INTRODUCTION

Under this heading, only the value chain from materials to the PV module will be considered. Systems and system components will be treated in Chapter 5 Products and Applications.

A few definitions should make it easier to understand the following sections:

Solar cells are in general semiconductor devices that convert light into electric energy. First solar cells were made from semiconductor silicon, and this technology is still alive. Crystalline silicon solar cells in their different forms - monocrystalline (Cz-Si), multicrystalline (mc-Si), ribbon – have a market share of more than 90%. Starting material to produce the solar cell is a sheet of silicon, the '**wafer**'.

PV 'modules', the basic power generating units of any photovoltaic solar electric system, are composed of a number of solar cells connected by metallic leads to deliver the right output voltage and current. They are encapsulated in polymers between suitable protective covers, normally a glass front sheet and plastic or glass rear sheet, and often framed to provide additional strength and allow easier mounting. Modules are generally robust, weatherproof and reliable, typically having producer guaranteed lifetimes of 20 years or more.



Thin film technologies use deposited thin layers of semiconductors, mostly on glass substrates, to produce solar cells. Their main advantage is that they require much less of the expensive semiconductor material. The large-area deposits are trenched into small stripes of individual cells that are connected to give the right electric output. Thin film technologies are in an earlier state of industrial development and have now a market share of below 10%. Main semiconductors used are amorphous silicon (a-Si), Cadmium Telluride (CdTe), and a number of compounds from the chalcopyrite group like copper indium diselenide (CIS).

Alternative technologies like the dye-sensitized solar cells and plastic solar cells are in an earlier stage of development and are of minor industrial importance up to now.

4.2 ANALYSIS OF THE SITUATION

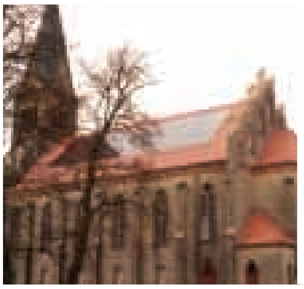
Most solar cells are made from crystalline semiconductor silicon, the rest being thin film technologies, mainly amorphous silicon (a-Si). Crystalline silicon solar cells are largely based on technologies and device structures well known from the electronics and microelectronics industry.

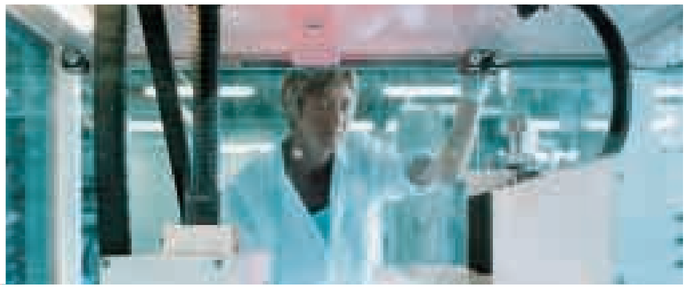
In case of the crystalline silicon technology large scale production is already common, and the equipment industry is now able to deliver complete production lines. The thin film technologies are still in the pilot stage, and one of the major challenges is efficient production equipment for mass production.

Cost of production is still rather high, but all technologies have an appreciable potential for cost reduction. Today, main effort of research and industrial technology development is directed towards reducing the production cost. Since materials cost is a substantial part of the total cost, reduction of materials consumption is essential, especially in the case of crystalline silicon. Since the selling price of modules is determined by the price per unit of peak power delivered by the module (€/Wp), efficiency enhancement of the solar cell also reduces the specific materials consumption.

As far as technology is concerned EPIA assumes in the Roadmap that crystalline silicon technology will remain the dominant technology at least for the next 10-15 years. Thin film technology will increase its market share. In particular EPIA feels that in building-integrated photovoltaics (BIPV) thin film may play an important role.

In the course of the analysis a number of research and development items have been identified. It has become clear that many of the defined tasks are best solved in concerted action of PV industry with partners from the research community, either research institutes or universities, and with partners from other industries.





4.3 DETAILED DESCRIPTION OF TECHNOLOGIES

4.3.1 GENERAL REMARKS

Silicon has become the mainstay of the solar electric industry because it is widely available, well understood, and uses the same technology developed for the electronics industry. At the present time 90% of module production is based on 'thick' crystalline silicon cells. EPIA and its members expect this domination to continue up to 2010 and beyond.

The production of PV modules based on crystalline silicon wafers is composed of three very distinct technologies:

- The value chain for the production of silicon wafers
- The device processing of the solar cell
- The fabrication of the module.

Technologies in these three steps are completely different and can be handled by independent companies.

The thin-film technologies use a completely different scheme. The preparation of the semiconductor layers, the fabrication of solar cells, the interconnection of cells, and finally the protection of the cells are in general combined to one process chain. This principle of in-line production, combined with the lower consumption of expensive materials, are the main reasons to believe that on the long run the thin film technologies might show a higher cost reduction potential as compared to the crystalline silicon technology.

High quality standards are set for the PV module: It should show high conversion efficiency, combined with an extremely long useful life of more than 25 years under outdoor conditions. On the other hand it is expected that the product should be fabricated at fairly low cost. This is the basic conflict of the production of PV products.

The biggest challenge in the production of PV modules is cost reduction, at the same time maintaining or even improving the quality of the product.

It is obvious that extensive research and development is required for all steps of the value chain, and this is true for all types of PV technologies. In addition, quality control is essential if the industry wants to keep the high standard already achieved for most of the products.

Module prices are expected to reduce to 2 €/W when cumulative production reaches 12 GW. This will be achieved in 2009 if the 27% market growth rate can be sustained. Ex works prices of 2 €/W are achievable with thick crystalline silicon technology within this timeframe, using technology currently available in the laboratory. However this is reliant upon availability of affordable feedstock and on transferring pilot techniques for thin wafer production to the commercial production line.

There are inherent limits to the extent that thick crystalline silicon manufacturing costs can be reduced.

The impact of manufacturing facility up scaling, larger area, thinner wafers, reduced kerf loss, reduced breakages and higher cell efficiency, etc. are finite and eventually material prices will dominate further cost reduction potential. At this time it will become critical that alternative technologies requiring less raw material and offering further potential for cost reduction, while continuing to offer similar performance and durability to the products they will supersede are ready for market. This implies thin-film technologies or concentrating PV systems which focus high intensity sunlight onto very small areas of photovoltaic material need to be available in advance of the manufacturing cost stagnation point for crystalline silicon modules.

Given the urgent need for low-cost solutions for developing country applications in particular, EPIA strongly supports the development of thin-film production processes parallel to the wafer technology and concentrator systems.

4.3.2 CRYSTALLINE SILICON

Feedstock requirement and pricing

At the current time, the vast majority of silicon available for processing by the PV industry is off-spec material from the semiconductor industry and "non-prime" electronic grade silicon intentionally produced by the silicon producers for solar application. Prices range from 20 to 29 €/kg depending on quality and amount of material purchased.

EPIA's Crystalline Silicon Technology Working Group has undertaken an estimation of the availability of suitable low-cost feedstock from the electronic polysilicon industry in the timeframe to 2010. Even assuming the PV industry manages to reduce its specific silicon consumption from the present level of 14 tonnes per MW of production to 12 and 10 tonnes per MW in 2005 and 2010 respectively, and assuming the electronics industry itself grows at 10% per year, it is clear that there will be a shortfall in availability of affordable material. Based on the 27% growth rate, the shortfall of economically prized silicon could be as much as 5000 tonnes in 2005 and over 22000 tonnes in 2010.

A number of companies worldwide are working to alleviate this problem through the development of dedicated solar grade silicon (SoG-Si) production plants, including Wacker, Joint Solar Silicon, SGSilicon and Tokuyama, and this may provide in the order of 1500 to 3000 additional tonnes of silicon at a price in the range of 25 €/kg by 2006. Lower prices might be realized by fast deposition techniques like the fluidised-bed reactor or the tube reactor. EPIA would like to see the European Union supporting manufacturers to develop additional appropriate technologies for dedicated solar grade silicon production, including providing co-funding for a pilot reactor for SoG-Si production.



Crystallisation of silicon

To convert the high-purity silicon into a suitable crystal structure for solar cells the silicon is melted in quartz crucibles and from the melt either single-crystal ingots are pulled or the crucible bottom is cooled producing large multicrystalline ingots. The common technique for crystal pulling is the Czochralski technique, and the material is called Cz-Si. Whereas pulled single crystals are inherently round multicrystalline ingots (mc-Si) can be crystallised in square crucibles. These ingots are cut into blocks of suitable format for solar cells e.g. 150 mm x 150 mm and transferred to the wafering process.

The challenge for the ingot-technology is to increase the silicon yield from currently about 60% to about 90% within the next decade.

Cutting of ingots into blocks and wafering results in material losses of more than 50%. To avoid this loss of expensive semiconductor material, ribbon technologies have been developed for the direct crystallisation of silicon sheets. Currently, the most successful technique is the EFG process to crystallise octagonal tubes from the melt using a shaping tool. These tubes can be cut by laser into silicon sheets that can directly be processed into solar cells. Other new ribbon technologies are under development in Europe and Japan.

4 TECHNOLOGY DEVELOPMENT

Wafering of ingots

Blocks of single- or multicrystalline silicon are sliced into thin wafers of a thickness of around 300 µm using wire saw techniques. The use of 180 µm thin wires and SiC-particles as abrasive result in about 250 µm silicon kerf-loss. This accounts for a materials loss of nearly 50%.

Further development of this technology aims at reducing wafer thickness to 180 µm and further down to 100 µm while maintaining high yield above 90%. At the same time kerf-loss will be reduced down to 160 µm using thinner wires and smaller abrasive particles. Recycling of SiC abrasive slurry will be an important step to further cost reduction.

Solar cells

Main steps in Solar cell processing from wafers are the diffusion of the p-n junction, the metallisation of the contacts, and the application of an antireflection layer. For the metallisation screen printing is the preferred technique although for high efficiency cells other techniques are available.

Today industrial solar cells typically have efficiencies of 16,5% for Cz-Si, 14,5% for mc-Si, and 14% for ribbons. In the laboratory, however, much higher efficiencies have been realised, e.g. 24,5% for monocrystalline cells and 21% for multicrystalline cells. This is an indication that there is much room for quality improvement of solar cells in production.

The solar cell efficiency targets to be approached on an industrial scale for the years 2010 and 2020 are set to the following values by this roadmap:

- 20% and 22%, respectively, on mono-crystalline Cz-material
- 18% and 20%, respectively, on multi-crystalline silicon
- 17% and 19%, respectively, on silicon ribbon material.

For the first two materials the thickness of the wafers will decrease considerably compared to now, approaching a thickness of around 100 µm or below in the next 10 to 15 years.

An additional development thrust will be to eliminate the expensive silver contacts and replace them by Al or possibly Cu without loss in efficiency. Any change in contact materials or contact geometry, like the back-contacting scheme, will have an impact on the interconnection techniques used in module fabrication.

Modules

Assembling of modules is a crucial step in the production chain since this device is responsible for the long life of PV products. High quality materials and special care in the fabrication are essential to pass the qualification tests.

Today companies guarantee a lifetime of their crystalline silicon modules of 25 years and even more. The advancements in this area are focussed on reducing the cost of the encapsulation material and to increase the life expectancy of the module to 35 years.

Furthermore, instead of using the current string technology to connect individual solar cells a back-contacting interconnect technology will be developed to reduce cost and allow for easy automation.

Plant size

Plant size has a key impact on unit cost. Scaling up of production units allows a high degree of automation. In-line processing and advanced process equipment will lead to continuous cost reduction in all steps of the value chain from silicon to module.

Reduced and environmental impact of PV module production

Although the environmental impact of PV production is small compared to conventional energy technologies, industry acknowledges the potential for further reducing PV's environmental footprint. Points of immediate concern are the use of large volumes of acid and alkaline etchants, the use of toxic lead in solder and in metallisation inks, the use of silver - a metal of limited resources - for metallisation and the relatively high energy consumption of the current production process. In addition, recycling schemes for modules will be developed further to reduce the environmental impact of PV solar electricity. EPIA proposes an EC-Industry-Academia partnership to focus on these issues.

4.3.3 THIN-FILMS

Thin film technologies today have a world-wide market share of about 10%. Main visual differentiation of thin film modules is the homogeneous appearance which opens new market segments according to customer needs related to the design of the modules.

4 TECHNOLOGY DEVELOPMENT

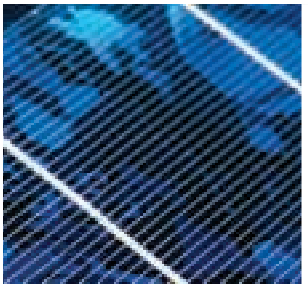
General remarks

Thin film modules are produced by depositing thin layers of semi-conductive material on glass or metal substrates with an integrated series connection of cells. This approach allows for higher automation if a certain production volume is reached. However, today's process technology costs per Watt peak for thin film modules are in the same range or higher as compared to crystalline modules, due to the small production units and low efficiencies of these modules in some cases. Nevertheless, in certain applications like the building integration the better appearance of thin-film modules compensates the sometimes inferior electric quality, and thin-film modules are penetrating into this market segment.

Companies that deposit functional layers on architectural glass are used to work with fairly large glass sheet. Application of these well developed techniques to the deposition of active layers for solar cells may soon lead to remarkable cost reductions through a dramatic increase in throughput of production lines. This will probably demonstrate very soon the real advantage of large-scale production in thin-film techniques.

Amorphous silicon (a-Si)

Of the various thin-film technologies, amorphous silicon is the best understood and accounts for virtually all of commercial thin-film production at the present time. This is expected to continue in the timeframe to 2010, with a-Si and hybrid cells of amorphous silicon and microcrystalline silicon expected to provide some 75% of all thin film production. Since the introduction of amorphous silicon to the PV market in the early 1980s, efforts have concentrated on improving the stable efficiency of modules by introducing better transparent front contacts and back reflectors, as well as multi-junction concepts.



Commercially available modules show stable efficiencies in the range of 5 % to 10 %. Present R&D efforts for amorphous silicon continue to seek further cell efficiency improvements and to increase the deposition rates to enable more rapid production of reliable modules.

Compound semiconductors

Europe has a long scientific tradition in research and development of polycrystalline compound semiconductors like cadmium telluride and the chalcopyrite group like CIS, CIGS, and others. Pilot production started in both areas, and decision about the investment in first production size units is expected within the next two years. Compared to amorphous silicon these compound semiconductor solar cells have higher efficiencies and good stability. At present, module efficiencies of 12 % - similar to mc-Si modules – have been realized. What remains to be proven is that they can be produced at similar cost as a-Si- or mc-Si- modules. This will become obvious if the first large production units become operational.

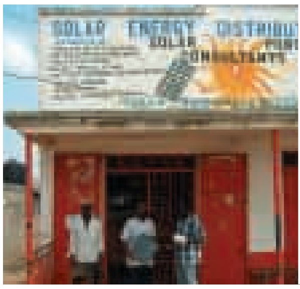
Research and technological development

European scientific institutes and industries play an important role in developing innovative cell concepts. However Japan's market share of thin-film panels is growing, due to the long experience of the Japanese industry in this field, and due to massive investments.

Thin-film solar cell technologies need continuous long-term development support, as well as short term demonstration support for applications and manufacturing, with a shift in focus from raising performance to considering the price/performance ratio. To better benefit from the research there must be dedicated support for technology transfer from science to industry. Stimulating the involvement of suppliers of manufacturing equipment is very much needed.

Encapsulation

The long-term reliability of PV modules and particularly thin-film devices is critically dependent on the protection of the sensitive semiconductor material from the environment, and particularly water ingress. In most cases glass panels are laminated to the substrate panel using EVA or acrylic resin, and an aluminium frame, which also adds strength and assists with mounting, protects the edges of the laminates. The industry needs to focus research on addressing encapsulation shortcomings, for instance through the adoption of flexible polymer framing technologies.



4.3.4 OTHER INNOVATIVE TECHNOLOGIES

In the longer term, thin-film silicon cells deposited on temperature resistant ceramics or transferred from a temperature resistant backing may offer an attractive price to performance ratio for many applications. However future developments include further optimisation of the previously identified cell concepts (efficiency and reliability improvements, simplification of cell and manufacturing process) and development of new concepts such as polymer solar cells and other types of organic solar cell.

Thin-film solar cells on the basis of gallium arsenide (GaAs) and other III-V-compounds show the highest conversion efficiencies measured so far. They are rather expensive because they can only be fabricated by epitaxial techniques using mono-crystalline GaAs or germanium substrates. Today they are used mainly for space applications, but terrestrial applications are under investigations. They are ideally suited for concentrating systems where the area price of solar cells is of minor importance. Solar cell efficiencies of nearly 40% under concentrated light have been demonstrated in the laboratory, and concentrating systems have shown efficiencies of 25% and more.

4.4 ACTION PLAN

4.4.1 GENERAL EFFORTS AND EXPECTED RESULTS

As has been pointed out the general goal of all effort in the development of photovoltaics must be directed towards the cost reduction on the entire system installed and towards the improvement of quality and longevity. It is obvious that all steps in the value chain have to make their contribution to reach this goal.

In the technology chain from starting material to the PV module, a few general goals can be defined as follows:

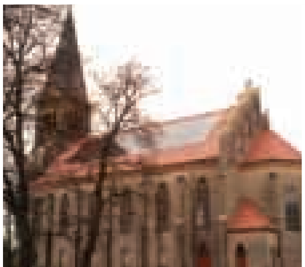
- Ensure the adequate supply of raw material
- Secure high solar cell efficiencies by using high quality starting material, excellent crystallisation techniques, and adequate solar cell processing technologies
- Ensure low consumption of the more expensive materials, e.g. by using very thin wafers, by using low-cost contacting schemes
- Secure the long life of modules by improving interconnection techniques and by further development in the field of materials for encapsulation and framing.

These complex goals can only be approached by a cooperative action of industry and the research community.

It is expected that due to this effort the cost reductions of components and systems will follow the extrapolation of the price experience curve as described in Chapter 7.1. In addition, the confidence of the users in their PV systems will grow, further pushing the positive development of the market.

4.4.2 LIST OF TARGETS AND ACTIONS

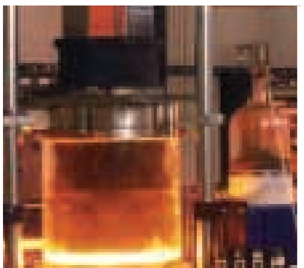
The following table lists the proposed actions (examples), targets and milestones, the specific efforts and the actors addressed:



MILESTONES FOR EPIA ROADMAP: Technology

Topic	Time	Goals	Action Items/Actors
Solar Grade Silicon	2005	**Operational plant** of 1 000 tons/year, increasing to meet the demand of the PV industry.	**Development up to mass production** Chemical industry, Research Institutes
Wafer	2010 (2020)	**Materials consumption** for Cz-Si and mc-Si from 16g/Wp to 10g/Wp (continuing to 8g/Wp) **Ribbons** from 10g/Wp to 6g/Wp (continuing to 5g/Wp) **Wafer thickness** from 300 µm to 180 µm (continuing to 100 µm) **Kerf loss** from 250 µm to 160 µm (continuing to 150 µm)	**Development of new wire saws** for Cz and mc-Si Equipment manufacturers and material suppliers **Improvement of material quality** Wafer makers and Research Institute **Productivity increase** for Ribbons, Cz and mc-Si (e.g. increase ingot size, increase silicon sheet area per time) Wafer makers and in-house producers, Research Institutes **Reduce cost of consumables** for all technologies and processes Wafer makers and in-house producers
Solar cells	2010 (2020)	**Crystalline Cz efficiency** from 16.5% to 20% (continuing to 22%) **Crystalline mc efficiency** from 14.5% to 18% (continuing to 20%) **Ribbons efficiency** from 14% to 17% (continuing to 19%)	**Develop new processes and cell concepts** Research Institute and Solar Cell Industry **Material and consumables cost reduction** Equipment manufacturers, material suppliers and cell makers, Research Institutes **Decrease processing time** per cell with new automation concept and increase area per cell by improving yield Automation industry and cell makers
Modules	2010	**Life time expectancy 35 years**, e.g. longer lifetime encapsulation materials **Interconnect technology**, e.g. back-contacted solar cells	**Develop new processes and concepts** Research Institute, equipment and module industry **Material and consumables cost reduction** Equipment manufacturers, Research Institutes, material suppliers and module makers
Thin film	2010 (2020)	**Process area** from 1m² to 3m² (continuing to 9m²) **2 routes:** 1. Thin film aiming at efficiencies between 10% and 12% (aSi/µcSi, CIS and CdS/CdTe) (continuing to 15%) 2. BIPV low cost per m2, price reduction of 50% (continuing additional 50%)	**Improvement of the TCO** Research Institutes, equipment and thin film industry **Improve stability** Research Institutes and thin film makers **Develop new processes and cell concepts** Research Institutes and thin film industry **Increase the deposition area** Building sector, equipment and thin film industry
New concepts	2010	First production plant for **dye-sensitised solar cells**, piloting **organic** and other **novel concepts**	**R&D to create a range of colours of dye-sensitised modules with sufficient outdoor life** Research Institutes (with Industry involvement) **Pilot plant followed by a first production plant for dye-sensitised cells** Research Institutes and PV Industry **R&D for organic and novel concepts** Research Institutes, Industry **Material and new solar cell concepts for more than 40% efficiency** Research Institutes

Source : EPIA



5 PRODUCTS AND APPLICATIONS

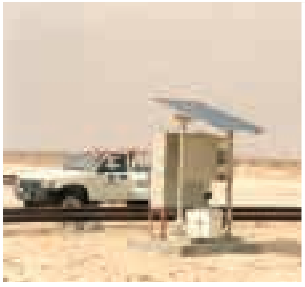
5.1 INTRODUCTION

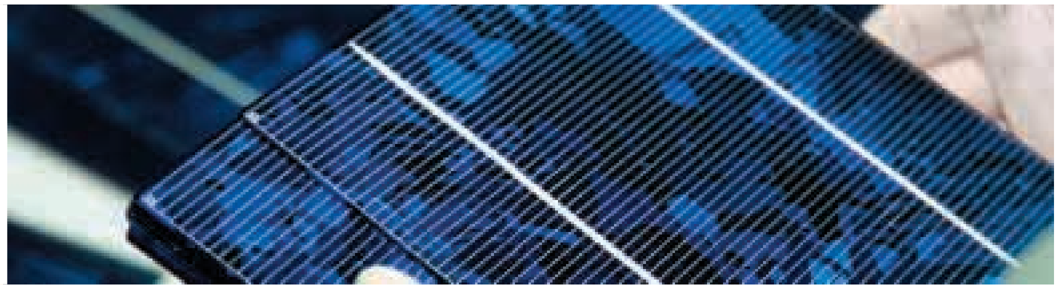
The module described in Chapter 4 is just a generator of electricity, of DC electricity in general. It is the PV system that delivers the required service to the user:

- **The system has to account for the intended use of the electricity**, e.g. for lighting, water pumping, telecommunication, feeding into the electric grid, and others
- **The system has to account for the characteristics of solar energy delivery**: e.g. dependence on location, weather, time of the day, direct or diffuse light, etc.

Important decisions are: DC or AC, voltage of the system, storage of electricity or not, alternative back-up generator, mounting of the modules, etc.

The type of the system determines which other components are needed to build up the system.





All components besides the module generator are called 'Balance-of-System (BOS)' components. Some of these are conventional mechanical (e.g. the module mounting) or electrical components. Very special for PV systems are 'inverters' to convert DC electricity into AC current, and 'charge controller' for the charging of batteries, if storage of electricity is provided. These two components for power conditioning offer a new opportunity for the electronics industry, and a number of companies are working successfully in this area. Because of an early recognition of the potential of PV, European companies have an excellent position in this market segment.

5.2 PV FOR GLOBAL POWER SYSTEMS

5.2.1 THE CONCEPT

Electricity consumers until now are predominantly connected to a central utility grid supplied by a power station of high capacity. These utility grids provide the end-user with AC power of a relatively fixed frequency and voltage (e.g. 230/400 V of 50 Hz). The central power stations can be complemented by decentralised supply structures which are characterised by relatively small generation units located nearby the consumers. Such a decentralised supply concept can effectively use the locally available renewable energy resources, especially solar, wind, biomass and small hydro. Moreover, it reduces the energy losses that occur due to voltage level conversion and long power transmission lines. Accordingly, the overall efficiency is increased, the economic situation of the region is improved and the conditions of sustainability are fulfilled.

The distributed nature of renewable energies matches perfectly this decentralised supply strategy. Depending on the regional conditions, the decentralisation concept can be fulfilled either by connecting a PV power plant (in the kW to MW range) to suitable points of the utility grids or by installing stand-alone systems and island grids in order to supply off-grid consumers. Accordingly, the decentralised PV system configurations used to supply AC power can be classified as follows:

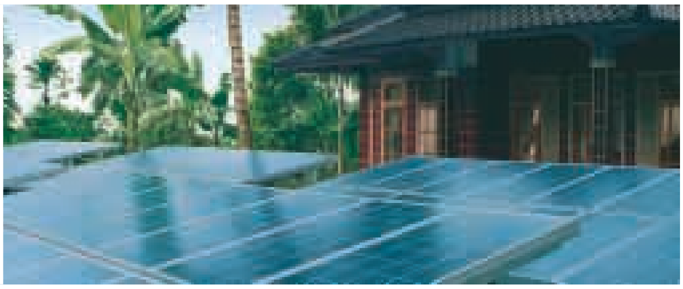
A. PV in utility grids

- Only PV
- PV with battery storage

B. PV in off-grid applications

- PV battery systems
- PV hybrid systems





All these supply configurations are shown in Fig. 1 and can be modularly structured. The grid connected structure is the dominant PV application area in industrialised countries such as Europe, Japan and the USA. If the PV plant is equipped with the suitable power conditioning unit it can supply power to the utility grid, as shown on the right hand side of Fig. 4. Integrating the PV plant with storage media (usually a battery) improves the energy supply availability of weak grids (back-up function).

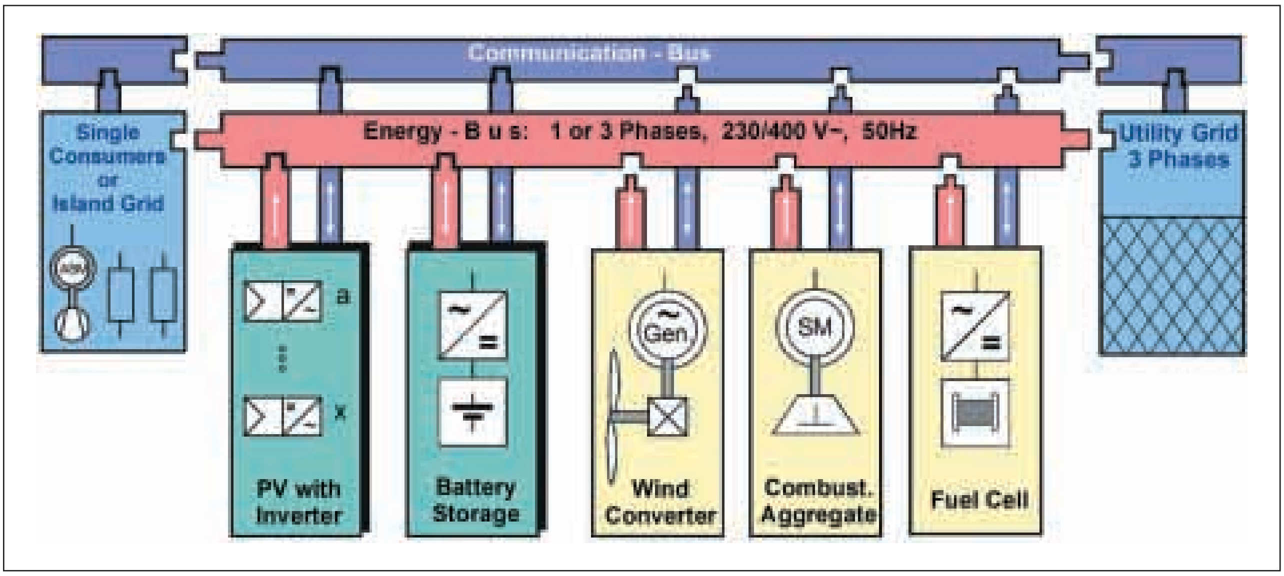
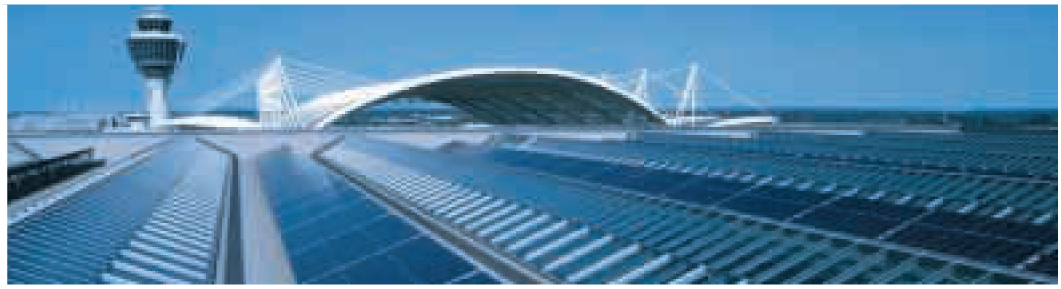


Fig. 4: Construction kit of the modular and AC-compatible hybrid system technology with standardised modules, including the possibilities of supplying single consumers or forming island grids and feeding into the utility grid (Source: SMA)

5 PRODUCTS AND APPLICATIONS

In PV applications for island grids used to supply remote and off-grid consumers, the PV plant is integrated with battery storage in order to ensure the desired availability. For larger-scale applications the PV plant can also be combined with other energy converters (e.g. wind energy converters, diesel generators, etc.) and storage units to form hybrid power supply systems, as shown in Fig. 4.

Both grid connected and island grid applications require the implementation of an intelligent system technology (e.g. power conditioning and communication facilities) in order to achieve a market competitive PV supply. For example, the power conditioning units (e.g. inverters and converters that represent the heart of the PV system technology) have to be of high efficiency and low cost. In contrast



to the electrically driven inverters employed in conventional power units, the high conversion efficiency of PV inverters is a decisive criterion for the energy yield of a PV plant and hence the energy cost.

Until now, the lead acid battery with its different technologies is the dominant storage medium in off-grid PV systems. Due to its high costs (about 100 €/kWh), a battery is applied for short- and medium-term energy buffering. Additionally, auxiliary generators, driven by diesel engines or micro turbines, are used as a back-up unit in order to improve the supply security of these PV stand-alone systems. In the future, fuel cells are of increasing interest as back-up units, since they generate power more controllably and reduce greenhouse gases. According to the fuel cell technology, they can be fuelled either by natural gas or by biogas, which can be easily stored.

Fig. 5 shows how decentralised PV power systems will evolve.

- local (e.g. supply of single loads via stand-alone systems)
- regional (e.g. supply of amenities, businesses etc. via island grids) and
- trans-regional (coupling to utility grids).

These types of grids form supply structures which can be expanded step by step as the demand for electricity increases. A broad expansion of the decentralised electrification would automatically lead to the interconnection of local grids.

Communication technology has become a vital element for high supply reliability and cost-effective maintenance in power plants. In addition to the power-line coupling of the different system components and plants, another communication structure for control and supervision purposes is an essential feature for the decentralised power supply structures. Analogously to the management of centralised grid-feeding structures, the widely distributed large numbers of decentralised power systems have to be administrated. Each structure has to be equipped with the suitable communication technology, as shown by the dotted line in Fig. 5. In such structures there are many operators which often do not have the know-how to maintain and repair their systems, especially in threshold and developing countries. In order to provide a reliable operation, particularly stand-alone systems need well-trained operators for maintenance and repair. This can be achieved in a cost-effective way by means of a limited number of service centres with specialists who can carry out remote supervision and maintenance. Hence, the application of modern communication technologies for remote control is very important and must influence the design of supply systems and components which become more and more capable of communication at a low cost.

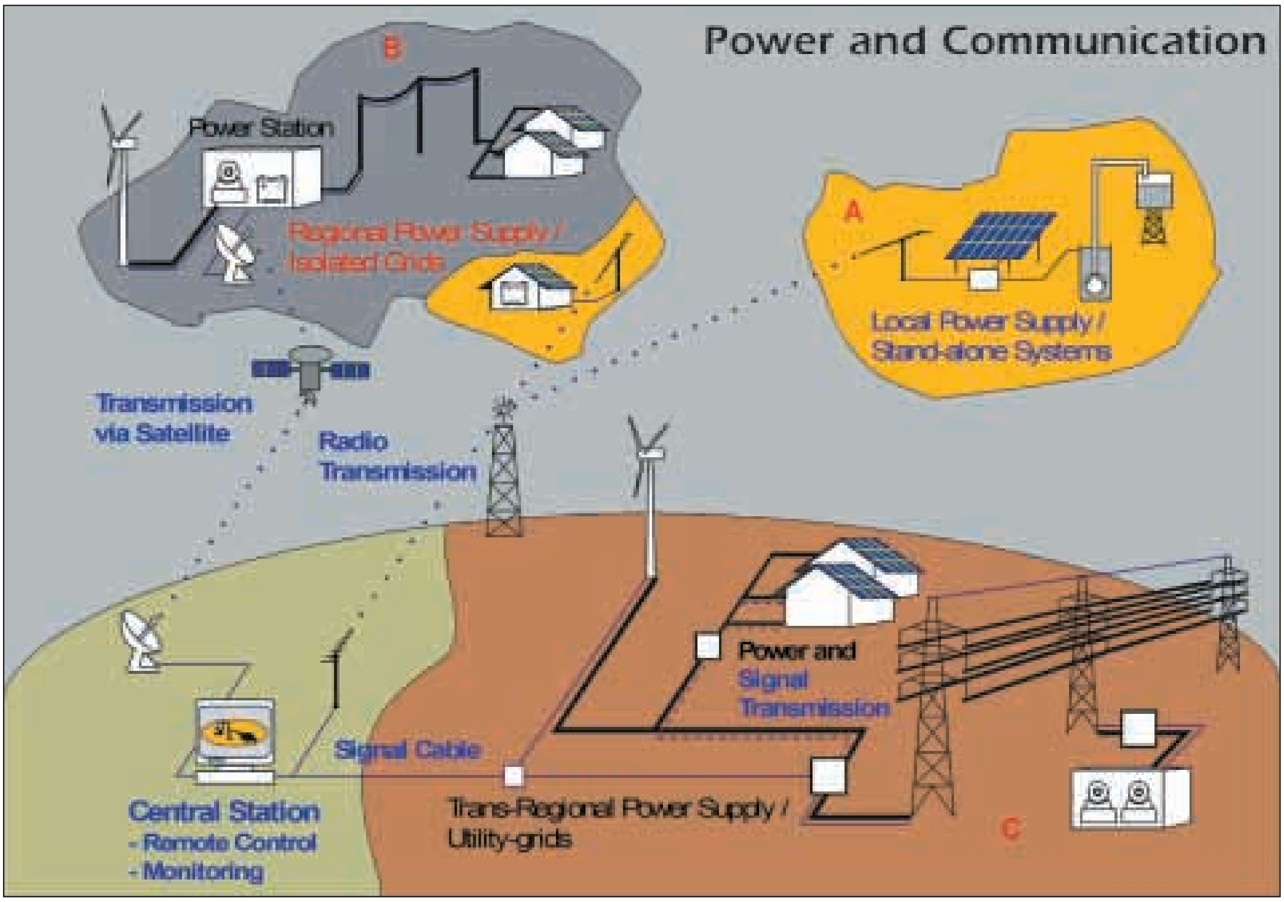
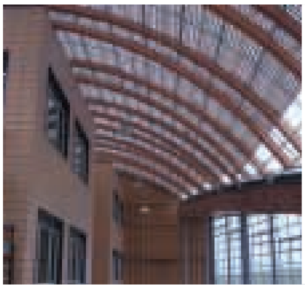


Fig. 5: PV and other renewable energies integrated into different electrical energy supply structures with communication and remote supervision facilities (dotted line):
A) stand-alone system (water pumping) B) island grid C) utility grid



EPIA anticipates such decentralised power structures to represent the future trend towards sustainable energy generation and to be the most intelligent model to follow in rural areas where large central power stations do not yet exist. The trend away from centralised power structures is also starting now in industrialised countries.

5.2.2 GRID-CONNECTED SYSTEMS

PV in European countries is mainly used in grid connected applications. Power conditioning units (inverters) play a key role in the energy efficiency and reliability of these PV systems. The energy produced by the PV module depends on the incident solar irradiation, module temperature and the operating point of the module. Therefore, the PV module requires a power conditioning component (Maximum Power Point Tracker) which can optimise the delivered power based on the operation conditions. The DC power generated by PV modules is previously inverted into alternating current (AC) of the desired voltage and frequency (e.g. 230 V and 50 Hz).

The basic inverter technologies for PV grid-tied structures are as follows:

- **Central inverters**: in this topology the PV plant (> 10 kW) is arranged in many parallel strings which are connected to a single central inverter on the DC-side.
- **String inverter**: the PV plant in this concept is divided into several parallel strings assigned to a designated inverter, so-called “string inverter”.
- **Module integrated inverter**: here one inverter is used for each module and usually small systems between 50-400Wp are employed.

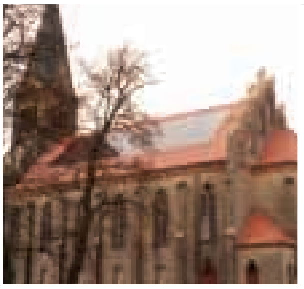
European manufacturers are producing all three types of inverters. It is up to the systems integrator to select the most appropriate inverter.

5.2.3 STAND-ALONE - AND ISLAND GRID SYSTEMS

Stand-alone and island grid systems are those PV power generation plants which are not connected to the utility grids. The island grid systems can be classified according to the voltage (DC or AC) they are coupled with. An overview of the three different system designs is described as follows:

1. **Solar-Home-System (SHS)**: all consumers and generators are coupled on the DC voltage level exclusively. This technology is nowadays commonly used for PV systems in the low power range. The solar-home-system (SHS) is the first realisation of stand-alone systems for domestic power supply purposes and is used for lighting, radio, TV, etc. Besides the PV modules it comprises a charge controller to ensure long lifetime of the lead acid battery.

   Today, several hundred thousands SHS have been installed mainly in rural areas of Asia, Africa and South America.



Supported by an additional small inverter, the consumer can use the DC-system to supply any standardised AC-load.

2. **Small AC local grid with DC-coupled components**: this technology emerged due to the need to supply (medium power) AC- loads from DC power sources and to charge the battery on the DC-side also from AC-generators like diesel gensets, refer to Figure 6. However, to couple multiple AC-generators of different kinds on the AC-side (e.g. diesel generators and inverters) a suitable grid forming control strategy has to be implemented. In this case the diesel genset forms the grid and the battery bi-directional inverter works as a battery charger. Such configuration is used to supply remote or rural consumers of bigger energy demand than the SHS (e.g. cottages, small workshops and farms). The common power range is between 1 and 5 kW and the DC-voltage range is between 12 and 48 V.

3. **Modular AC-coupled systems**: more flexible systems with a consequently modular structure system are achieved via coupling all consumers and generators on the AC-side refer to Fig. 1. This technology is today commonly used in the power range above several kW. According to the application type and energy resources availability, different renewable and conventional energy converters are also suitable to be added to the system to form a hybrid energy system. Since all converters, storage and back-up units of the decentralised systems can generate AC power of grid compatible characteristics, they are also suitable to be connected to the utility grid. Moreover, it can be expanded by integrating further island grid systems. Such structures are used to supply any electrical consumer, especially rural villages of developing and threshold countries where electricity, water pumping and water disinfection are basic needs.

This type of PV applications has a huge market potential, especially in developing and threshold countries which lack appropriate conditions for utility grid extension. The power range of these island grid systems varies between 3 – 100 kW. As mentioned above, the modular system has come up with very many advantages in simplifying the system engineering (design, installation, expansion and compatibility) and consequently minimising the specific system cost. The structure of such supply systems requires, in addition to the power conditioning equipment, a control and supervision unit which is responsible for implementing a specific operation control strategy and securing the grid and system components. In small and medium power systems (3 – 30 kW) this control unit is often implemented in the key component “battery bi-directional inverter” which simplifies system operation and decreases the investment costs.

From the economic point of view, small off-grid PV systems (with battery storage) in the kW range are definitely more cost-effective than systems using pure diesel generators. Even larger PV hybrid systems (5 – 30 kW) using diesel generator sets only to avoid large long term battery storage can operate at lower cost than pure diesel powered systems. This can be attributed to the high life cycle costs of the diesel generator set. For example, the generated kWh by diesel generator sets (10 – 30 kW) costs about 0,4 – 0,6 €/kWh.

5.2.4 PV POWER SYSTEMS – THE NEXT STEPS

PV currently supplies only a minute amount of electric power generated world-wide. Nevertheless, even today due to its decentralized nature it provides millions of people around the globe with a minimum of electricity to satisfy basic needs in communication, health and water supply. However, in order to achieve the goals of the EPIA Roadmap, system technology will have to reach the following milestones until the year 2010:

– Implementation of the modularisation concept with standardised components to be coupled on the AC-side that are compatible with the existing utility grid

– Integrating intelligent components with standardised interfaces and functions for control and communication (monitoring, diagnosis)

– Increasing conversion efficiency of inverters > 96 % and increasing input voltage range

– For island grids in particular, simple design and low maintenance and service costs in order to carry out the supervisory control task for the various components (converters, battery, etc.)

– Prefabricated systems for low-cost installations

– Cost reduction with increasing production volume for all components. As an example, Fig. 6 shows how prices of PV inverters decay in the past 10 years. EPIA expects this reduction trend will continue for the next 10 years

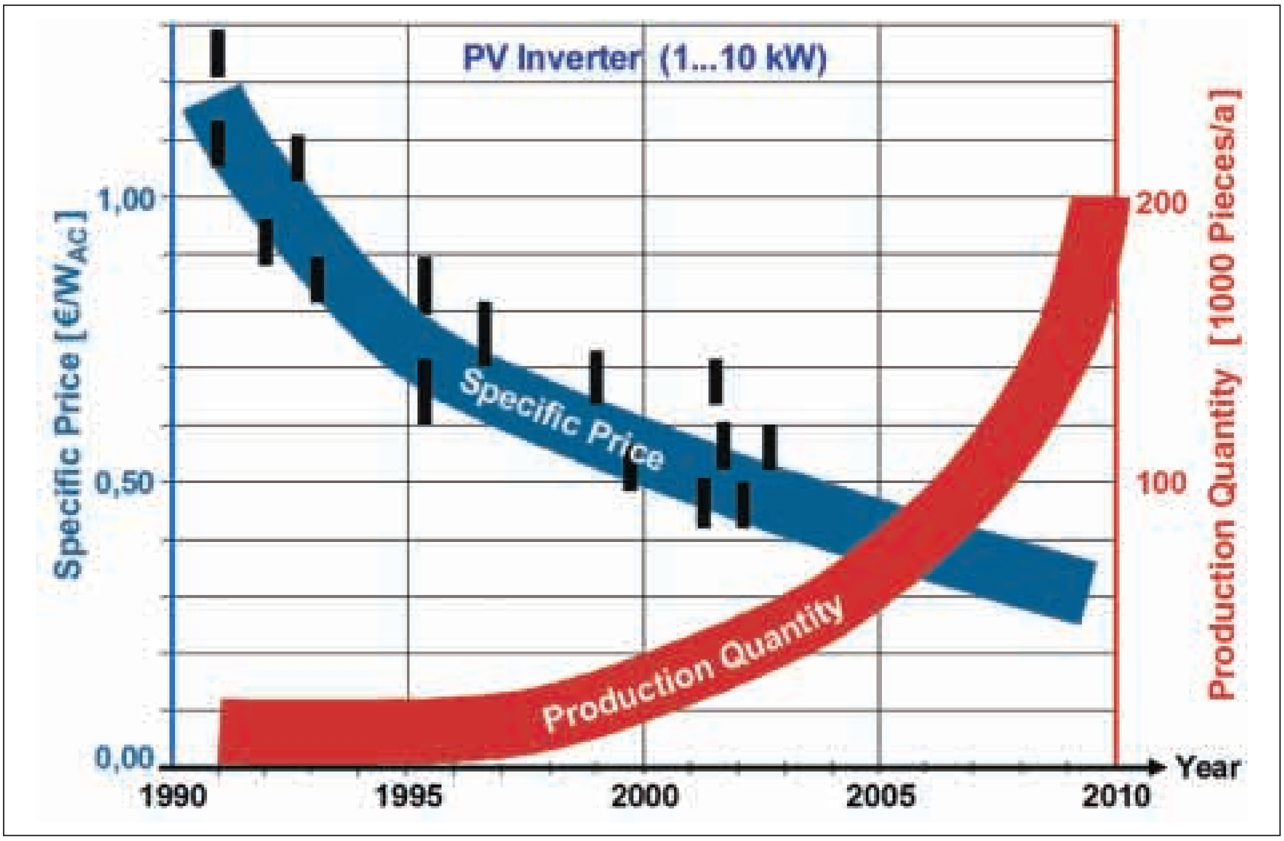


Fig. 6: Development and prognoses of specific cost and production quantity for the PV inverter of nominal powers between 1 and 10 kW during two decades (indicates specific prices of products on the market)

EPIA believes that price reduction as shown in Fig. 6 can also be accomplished for other electronic components such as charge regulators for small PV systems, DC-AC-converters as well as for control systems to monitor the widely distributed systems and be able to come up with effective diagnoses in case of system failures.

Provided the milestones listed above will be accomplished, EPIA predicts that off-grid PV and hybrid systems for village electrification will have lower kWh cost compared to the stand-alone grids using only diesel gensets. In order to demonstrate this on a larger scale, EPIA wants to carry out five large village electrification programs with PV-hybrid systems.

In the longer term, continuing the growth projection to 2020 shows a cumulative installed capacity of approximately 167 GW, corresponding to a module price marginally below 0.90 €/W. At this price, and assuming balance of system costs and installation realise similar percentage reductions, typical residential power generation cost from PV electricity in Germany for example would be below 0.20 €/kWh. For small systems, up to perhaps 1.5 kW, it will be very difficult to deliver these prices unless PV systems are provided in an appropriate kit form for installation by the end user as costs of professional installation will become disproportionately large. Even for systems up to 3 kW the installation costs (including system design) will need to be kept to no more than 2 person days, which implies that systems must become far simpler to install. Incorporation of standard, simple products such as PV tiles that can be easily fitted by a roofer within the general building process will be needed to achieve these price objectives. This not only requires the development of more cost-effective construction-friendly products, but also training for systems installers within general construction and/or electrical contractor accreditation programmes.

As for grid connected systems, realising the technological milestones mentioned above and with continuous growth of mass production, EPIA expects that prices of small integrated roof-top systems to come down from about 6 €/Wp to 3 €/Wp – 4 €/Wp by 2010 and be cost competitive with peak power generation. By 2020, EPIA expects grid connected PV systems to be price competitive with conventional power generation.

5.3 MANUFACTURER OF SYSTEM COMPONENTS

Two electronic devices are predominant in PV Systems, the charge controller in the stand-alone systems with batteries, and the inverter to generate AC from DC. Charge controllers are responsible for the long life of the battery. Since this is an expensive part of the system high quality of the charge controller is needed. Nevertheless, the life of batteries in PV systems is limited, and their replacement is the main reason for the high lifecycle cost of stand-alone systems. Improved batteries would be a real benefit for the PV installers, and additional efforts in their development would benefit the business in remote areas.

The inverter has to fulfil even higher expectations. Its common use is in grid-connected systems, and three properties are essential: High conversion efficiency, extremely long life, and meeting of the safety requirements of the utility. The quality of the inverter must fit to the highest industrial standard, on the other side the price of the device should be reasonable. Due to extreme effort of the industry, the quality of inverters has improved very much during recent years, and the large number of systems installed helps the industry to become profitable.

European producer of system components have been the leading companies in terms of development and production.

EPIA sees system technology expanding dynamically into all areas where customers need electric power, competing already successfully with conventional power in rural areas and reaching grid competitiveness in the next decade.

5.4 BUILDING-INTEGRATED PHOTOVOLTAICS (BIPV)

A number of applications of photovoltaic modules and systems around buildings have been found by architects and the building industry. Rooftop systems were in the beginning, and often are today, just attachment of PV modules on top of existing roofs. However, the ideal solution would be to make the module an integral functional part of the building. Very attractive and aesthetically pleasing examples can be found for PV facades, roofs, shadowing elements and other parts of the building.

In all cases, the module has additional function besides being an electricity generator: Sealing of the roof, thermal isolation and sound protection are examples. Since these modules have to be constructed according to building codes they tend to be expensive. This still rather small but high value market develops steadily and attracts the attention of the public. Special companies are engaged, mainly from the glass and the façade industries.

5.5 ACTION PLAN

Systems are the connecting elements between the main PV product, the PV module, and the user of solar electricity. EPIA actively supports every effort directed towards innovative solutions and improvement of efficiency, reliability and long life in order to strengthen the acceptance of PV products for decentralized electricity services.

The following table shows the proposed actions (examples), targets and milestones, the specific efforts and the actors addressed:

MILESTONES FOR EPIA ROADMAP: Systems

Topic	Time	Goals	Action Items/Actors
Systems On-grid	2010 (2020)	**From 6 €/Wp (for 5 kWp system) to 3,6 €/Wp,** e.g. prefabricated systems, cost competitive with peak power (continuing to 2 €/Wp)	**From year 2000-2010 a 5% price reduction per year for all components (modules, inverters and installation)** PV Industry, Research Institutes
Systems Off-grid	2010 (2020)	**Stand-alone, village grids, hybrid systems:** 1. Costs/kWh below diesel generator 2. Connecting villages to regional system	**International programmes for developing countries** Worldwide institutions and PV Industry **Benefits from the On-grid costs reduction action**
BIPV On-grid	2010	**Module as a standard building component**	**Standardisation of PV products** inside the Building sectors **Demonstrate cost reduction for PV** due to the module and installation being part of the building cost
Standardi-sation	2010	**Components and systems**	**Definition and improvement of standards** Semiconductor + Building Industry + PV Indus. + Utilities
Storage	2010 (2020)	**On-grid: storage for few hours** **Off-grid: storage for day(s)**	**Replacement and/or minimisation of lead-acid battery** Research institute and appropriate industry **R&D on fuel cells and solar hydrogen systems** Research institute and appropriate industry
Concentrators	2010 (2020)	**First economical PV plants using III-V semiconductors** and efficiency of 30% at 500 X (continuing to 35%)	**R&D on low cost lens and tracking systems** Research Institute, mechanical engineering and PV Industry **Pilot plant followed by a first production plant** Research Institute and PV Industry

Source : EPIA

6 INDUSTRY DEVELOPMENT

6.1 EUROPEAN PV INDUSTRY

6.1.1 STRUCTURE OF EUROPEAN INDUSTRY

In the strict sense PV industry comprises companies engaged in crystallisation and wafering of silicon, in solar cell production, module production, and thin-film module production. In this category we also count companies producing system components nearly exclusively for PV application.

In Europe, the whole value chain is covered by a number of companies, and most of them are represented by EPIA.

The companies have a very different background. Some are connected to big oil companies and utilities, but most of them are companies independent from the big industrial players. They are small and medium enterprises. This is especially true for the large majority of module producers.

Some of the companies are in the field for more than twenty years, but especially during the last few years a number of new companies started business, financed by independent investors.

6.1.2 MARKET SHARE OF REGIONAL INDUSTRIES

Fig. 7 shows the market shares of the industries in Europe, the USA, Japan and the Rest of the World (ROW) for the last six years. The strong position of the Japanese industry is obvious, but the European industry also shows a steady growth.

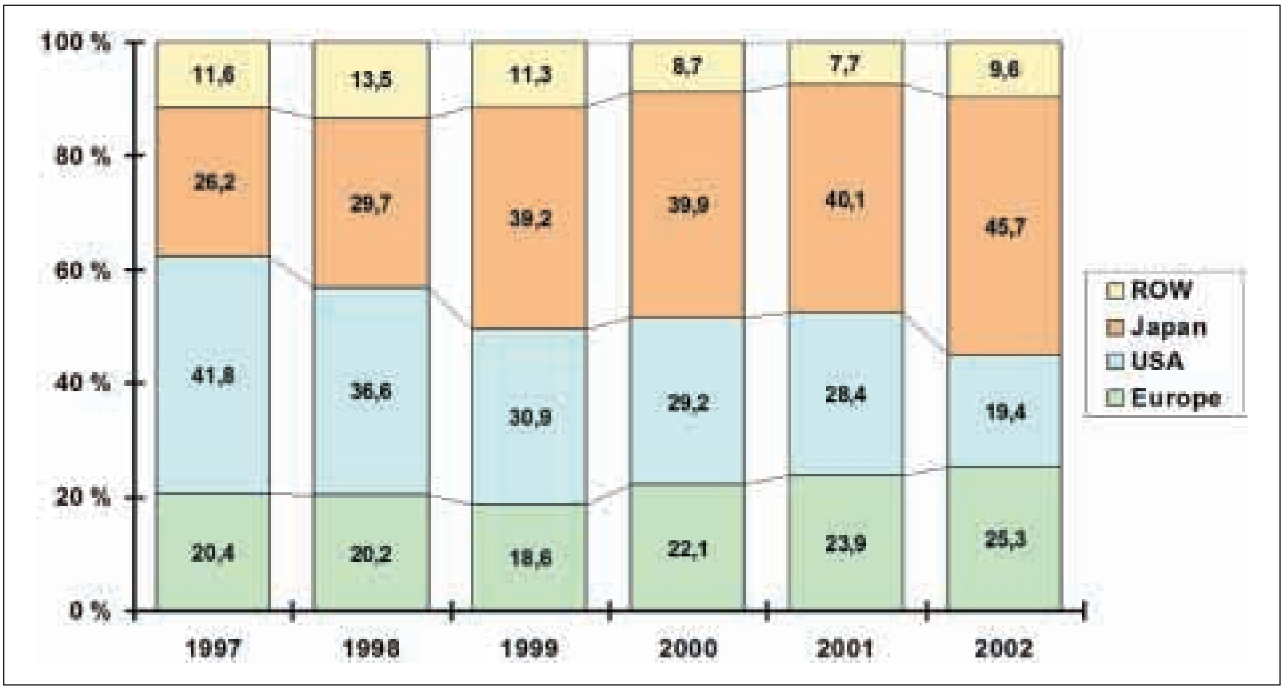
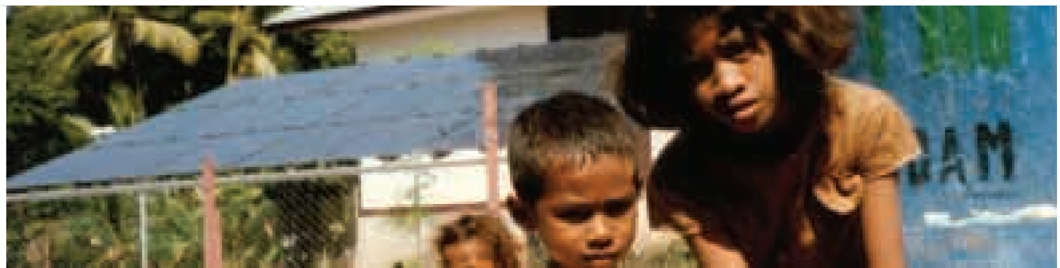


Fig. 7: Market share (shipments) of industries from different regions



6.2 SUPPLY INDUSTRY

For various process steps in the value chain the PV industry relies strongly on the delivery of materials from the outside. The importance of the silicon feedstock material delivered by the producers of semiconductor silicon has already been emphasised. It is really a crucial question for the silicon PV industry whether the silicon supply can be guaranteed for the strongly growing demand. But this is only one example of the dependence of the PV industry on materials from outside. Other examples are the silica crucibles for crystallisation, and the silicon carbide abrasive powder for the wire saws. Like in the semiconductor industry the PV industry needs the supply of numerous materials from the outside. Of course, the numerous jobs that are generated by those industries are also due to the PV market development.

6.3 EQUIPMENT MANUFACTURERS

Solar cell and module fabrication has started to become mass production. The importance of equipment manufacturers is growing since the solar cell and module producers are more and more dependent on the availability of equipment on the market. Investors in large solar cell and module production plants are not further interested in developing their own equipment, and it is true that during the last few years the equipment industry adopted to the high growth rate of the PV industry and now offers whole production lines with a high degree of automation.

In future, equipment manufacturers could become the driving forces for new technological developments, as it is already the case in the semiconductor technology. Therefore, they are very important partners for the PV industry for the advancement of technologies. The involvement of the equipment industry in the evolution of mass production from mid-size manufacturing is indispensable.

6.4 SYSTEMS INTEGRATORS

The end product of the PV industry is the PV module. A whole chain of distributors, system integrators and installers is found between the module producer and the customer who invests in a system. These are in general fairly small companies, and in fact there are hundreds or even thousands of them engaged in this business in Europe. It is save to state that the number of people employed in the businesses that are responsible for installing systems is much higher than the number of people in the production plants.

The small companies near the customer play an important role since they are really responsible for the acceptance of their products by the customers and for developing the market further.

7.1 MARKET DEVELOPMENT – THE FUTURE

EPIA anticipates sustained market growth of 27% per annum worldwide up to 2010 (in terms of annual module power generation capacity manufactured). However, it must be emphasised that such growth rates are heavily reliant upon strong policy support measures in particular to maintain and further develop demand for distributed PV generation systems within Europe and in the other main industrialised countries. Furthermore, in order for Europe to realise the target of 3GWp installed within the region by 2010, this implies that the rate of installation in Europe must be higher still – about 29% per annum. It should be pointed out that strong growth in Europe for the past four years is mainly due to the implementation of the German Feed-in law (EEG). EPIA strongly supports this program and favours similar policy measures for solar electricity in all countries of the Union.

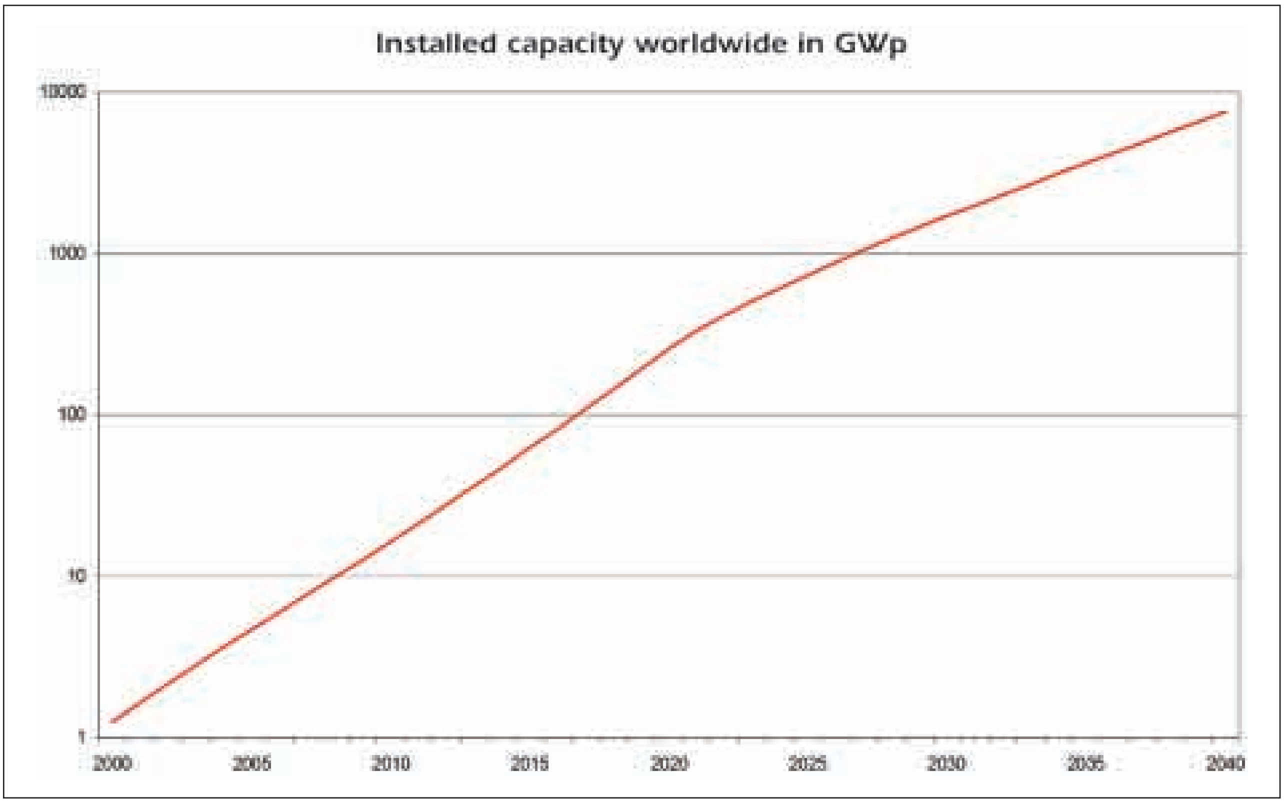
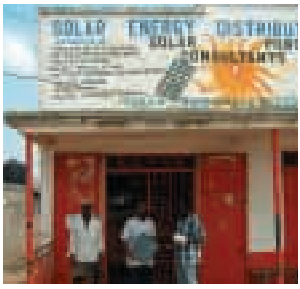


Fig. 8: Annual cumulative worldwide PV instalment until to 2040 in GWp

While growth for off-grid applications and for consumer products - has remained steady at about 15-18% per annum growth over the past decade, the grid connected markets have consistently exceeded 40% per annum growth and in recent years achieved 50-70% annual growth rates[3]. In the absence of any such support mechanisms the market would be expected to revert to the historical 'business as usual' growth of 15% per annum, which would have the effect of greatly delaying the point when PV generated electricity becomes competitive with conventional power generation methods as indicated below. Furthermore, we need to appreciate that Europe is not the only player in the global PV industry and other regions – Japan in particular - are likely to maintain or increase their commitments to solar PV development. In the absence of specific European national or Union level support mechanisms for PV, the European PV Industry will loose its currently strong position and is in danger of becoming marginal.



EPIA wants to point out that in the past promising technologies such as liquid crystal displays, optical components, etc. that were originally strong in Europe lost out to their competitors mainly in South East Asia due to lack of political support for these technologies.

EPIA strongly encourages European efforts on all policy levels so that PV solar electricity continues to strive and grow in Europe. In this context EPIA also supports the policy that with feed-in regulations the major part of the system must be of European origin.

Historically PV technology has demonstrated a price reduction of 20% per doubling of cumulative production[4]. Module price reductions have been largely mirrored by price reductions in balance of systems components and in installation. EPIA is confident that the 20% price-experience pattern will continue. In essence therefore, market growth and technology developments are largely the governor of achievable price reductions. It is clear therefore that increased consumer awareness coupled with appropriate support mechanisms to stimulate additional demand for PV products will serve to accelerate the timeframe within which PV becomes 'economic' in conventional measures of energy costs with other more established energy technologies. In the EPIA Roadmap price-experience curve for modules shown in Fig. 9 the 'starting' point of 1.4 GWp by end of 2000 corresponds to ca. 4.0 €/W. Since then the average prices have come down even faster than shown in Fig. 9.

[3] Interpolated from IEA-PVPS series of reports 'Trends in Photovoltaic Applications in selected IEA countries' from 1992 to 2001
[4] this has equated to approximately 5% per annum price reduction over the past decade

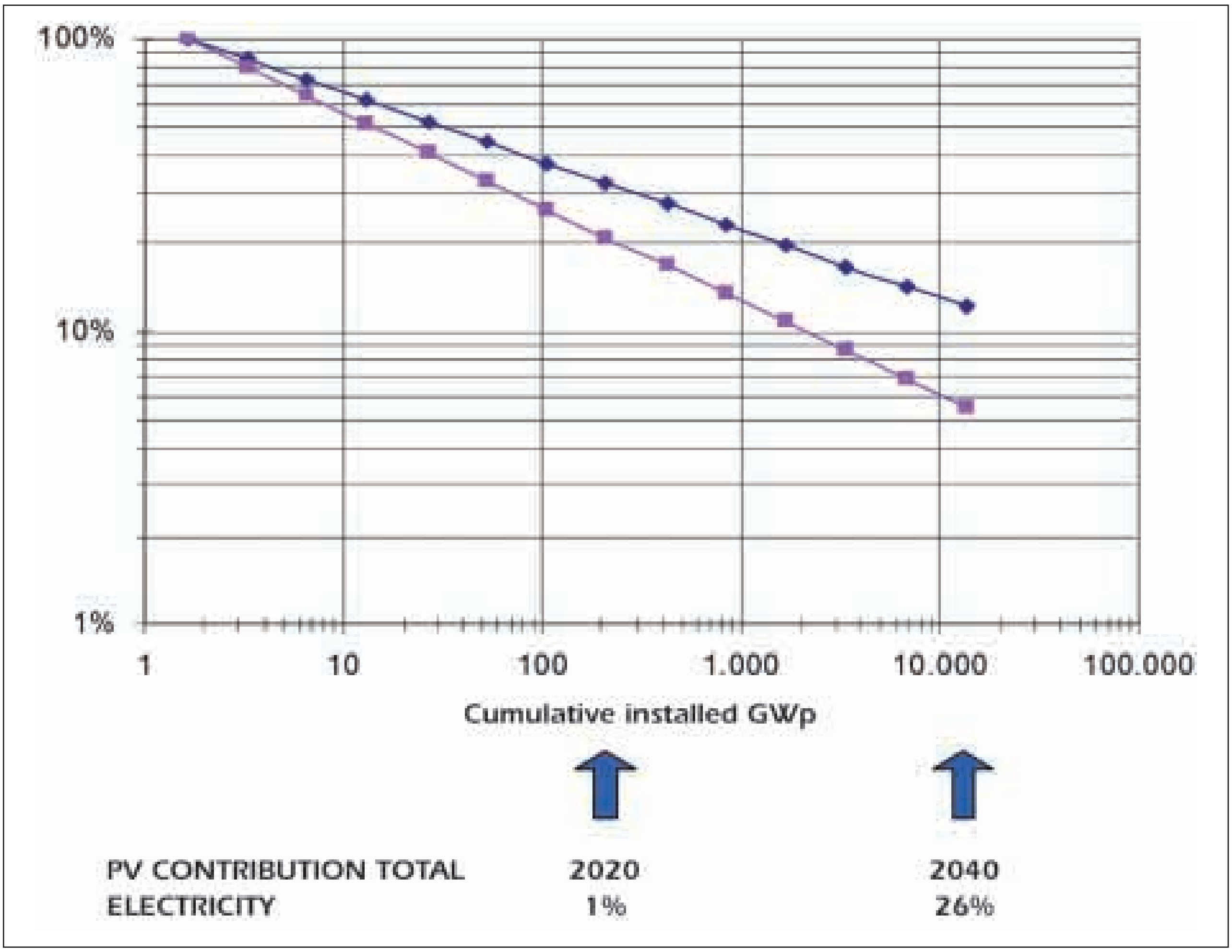


Fig. 9: Price-experience curve for PV modules
Blue line 15 % learning curve, red line 20 % learning curve (Source:PV Silicon)

The main application segments for PV are remote industrial (e.g. off-grid telecommunication repeater stations), consumer applications (e.g. PV for car sunroofs), developing country applications (mostly off-grid solar home systems) and grid connected systems. Historically the main market segments for PV were the remote industrial and developing country applications where PV power over the long-term is often more cost-effective than alternative power options such as diesel generators or mains grid extension. Worldwide, the share of off-grid to grid-connected applications is approximately 1/3 to 2/3 at the present time.

For off-grid systems major applications in developing countries could provide light, water, communication etc. However PV has the potential to deliver much more than just electricity. Applications as water purification, medical refrigerators etc are crucial considering that more than 2 billion people in the world do not have access to electricity.

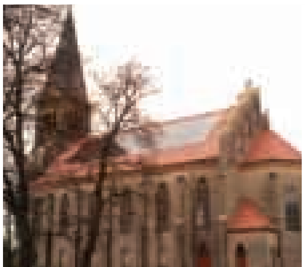


Fig. 10: Market segments of PV applications (Source: RWE Schott Solar)

The grid-connected and the off-grid systems are of highest importance for the development of PV in Europe and worldwide. EPIA foresees at least 3, 6 GWp by 2010 and 41 GWp by 2020 installed in Europe and worldwide. The adoption of the new EEG in Germany is expected to support the development of the European market. Targets set within the Berlin Conference context, foresee 35 GWp by 2020 with an annual growth rate of 27, 8% between 2010 to 2020. If the German support scheme to the market could be adopted by all European countries then we could achieve a much higher level than 3 GWp of cumulative installed capacity in Europe,and come close or exceed the goal of our major competitor in Japan of 4.8 GWp by 2010.

For solar electricity the geographical location of the PV-installation and the solar insolation directly influence the generating cost. Figure 11 shows that in the year 2000 for a typical location in Germany with 900 h sunshine/year cost of solar electricity was ca. 0.60 €/kWh while for the same installation in Southern Europe it would have been 0.30 €/kWh. Fig.12 also shows the impressive cost reduction since the year 1990 when the 1000-Roof-Programm started in Germany.

With the liberalization of the European electricity markets utilities will increasingly charge their customers higher rates for periods of peak demand. Such a period exists for many customers around noon time fitting ideally with solar radiation and PV is expected to compete successfully with conventional peak power in Southern Europe near the year 2010 (red curve in Fig.11).



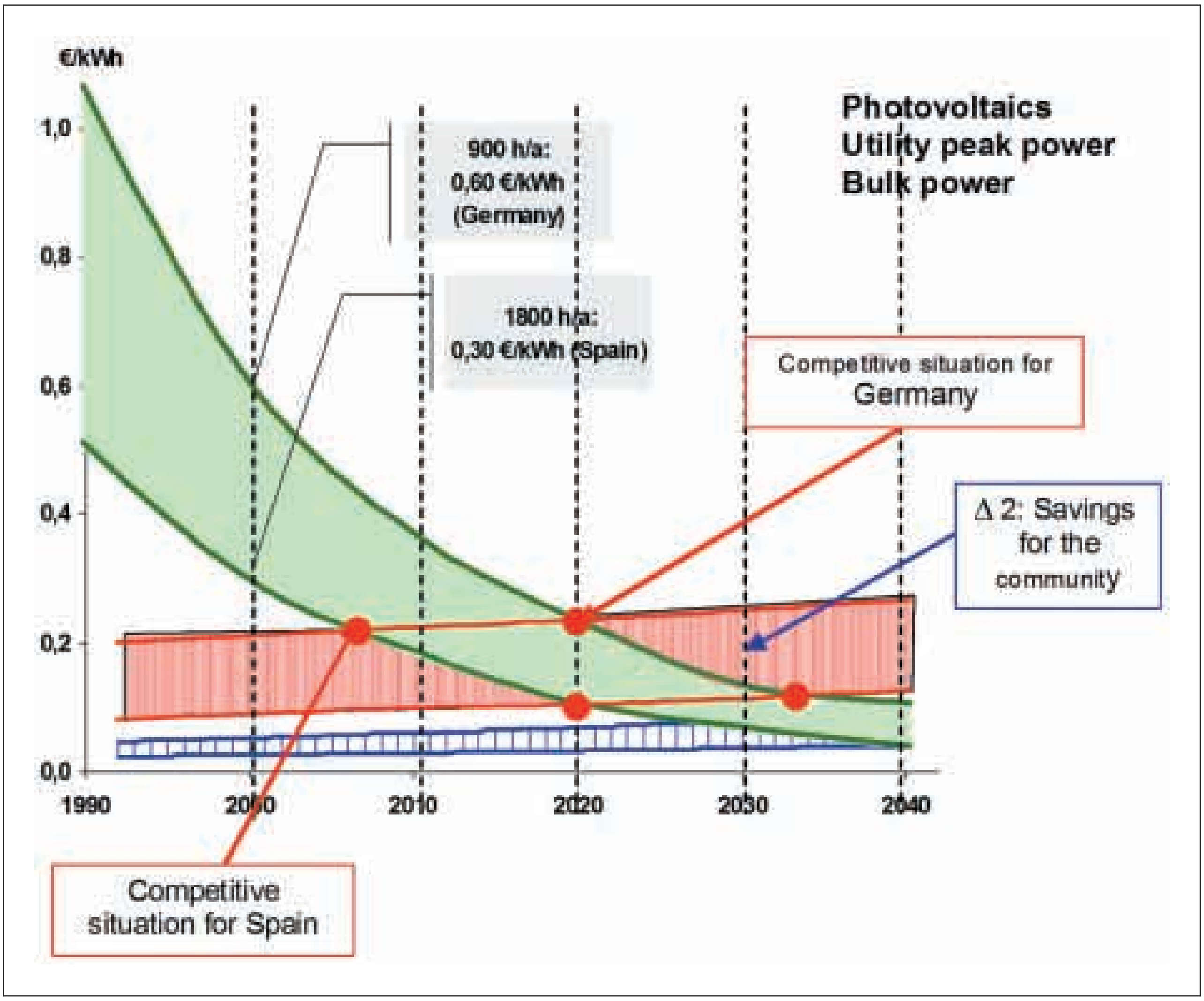
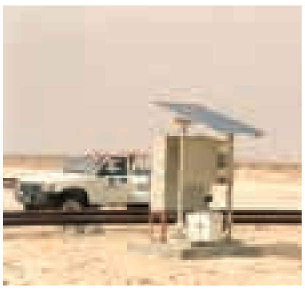
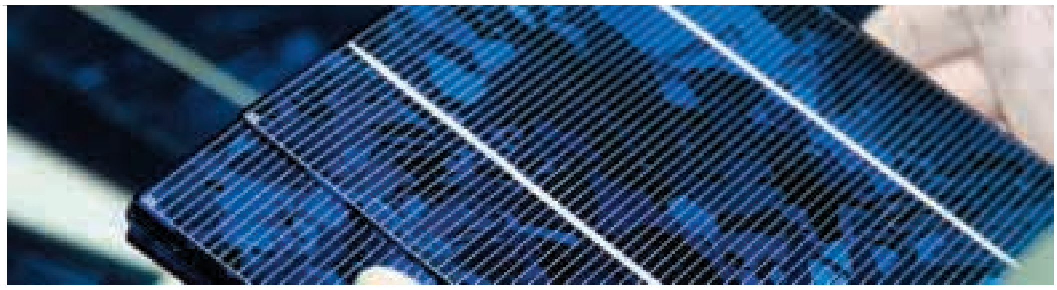


Fig. 11: Cost development of PV generated electricity vs. conventional price of electricity (Source: RWE Schott Solar)

With conventional bulk power generation plus its transportation to the customer PV Solar Electricity is expected to compete near 2020 in Southern Europe.

To achieve the goal of at least 3.6 GWp installed in Europe by 2010 and cost competitiveness with conventional power at a later stage, EPIA wants to realize the following support scheme:

- Feed in tariff
- Mandatory building integration
- Rural development with export activities

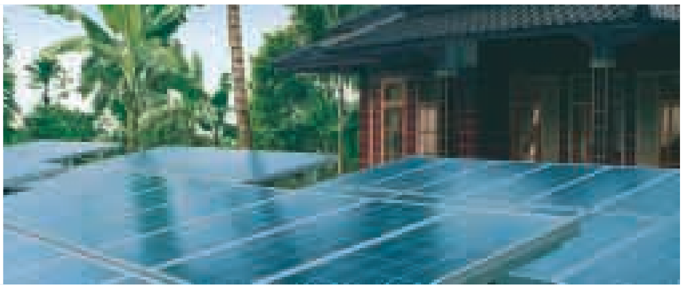
7.2 MARKET DEVELOPMENT IN EUROPE

7.2.1 POLICY INITIATIVES

- Successive pieces of legislation have been vital to creating Germany's position as the European leader in solar energy. In particular the favourable long-term feed-in tariffs, offered nationally since 2000 under the Renewable Energy Law (REL) which guaranteed 0.5 €/kWh for 20 years for solar electricity fed into the grid, coupled with low-cost loans have stimulated considerable demand for residential solar systems. The REL is fiscally neutral, funded via a small levy on electricity sales nationwide. The guaranteed price is reduced by 5% each year for new contracts which stimulates further system price reductions. One of the most important aspects of the German Renewable Energy Law is that it has provided a secure medium-term planning base for investment to help PV industry move from niche markets to mass production.

  This is not to say that other European countries are not acting to support PV. Far from it, in fact; realising the importance of such schemes to simultaneously meet environmental targets and develop innovative industries, other European countries have introduced similar regulations and/or subsidy programs, e.g. France, Italy, Luxembourg, the Netherlands, Portugal, Spain and the UK. Nevertheless, EPIA firmly believes that a coordinated pan-European rate-based incentive scheme similar to the REL would be a significant boost to European industry and a dynamically expanding market would serve to accelerate the cost-reduction process. If the REL had been implemented throughout the EU, for instance, the generating capacity installed since 2000 alone could be as high as almost 900 MWp – approximately 50% more than is installed in Japan and four times more than in the USA. It would also place the EU well on the way to achieving the 2010 target of 3 GWp installed.





- In the order of 2 million new dwellings are constructed in Europe each year. Building regulations that recognised and supports the role of PV for sustainably delivering electricity in the urban environment would stimulate a vast potential for PV installations, based on capturing a proportion of the new-build market and domestic rooftops. EPIA promotes the inclusion of a mandatory PV requirement within the new European building directive. A relatively modest requirement for PV on 5% of new buildings would stimulate a market in the order of 200 MW per annum within the residential sector alone.

7.2.2 MARKETING, EDUCATION AND STANDARDS

- PV is a young and relatively small industry, consequently its budgets for marketing is small. This means that potential customers are not reached during the vital industry transition period when new markets are emerging. To optimise small budgets, EPIA recognises that alliances should be formed with utilities, environmental groups, building developers and so on. Governments can and must continue to play a crucial role in technology promotion through general sector marketing (e.g. via support for European and national industry associations, and via public information campaigns – similar to the support offered for promotion of energy efficiency measures).
- Standards, guidelines and training are essential for successful market deployment, and high consumer confidence. As far as possible harmonisation of existing test and safety standards and building codes across Europe would remove current problems such as requirements upon PV inverter manufacturers to conform to different approval programmes across Europe. PV must be incorporated in standard technical and vocational training courses. Continued support must also be offered for training, certification and expansion of EU installer accreditation activities including cross-border recognition. Guidelines also need to be developed for best practices in relation to PV in the credit and building sectors.

7.2.3 ACTION PLAN

The following table lists the proposed actions (examples), targets and milestones, the specific efforts and the actors addressed:

MILESTONES FOR EPIA ROADMAP: Markets in Europe

Topic	Time	Goals	Action Items/Actors
On-grid	2010 (2020)	**At least 3 GWp** (cumulative in the EU countries) **(At least 41 GWp cumulative)**	- **Feed-in tariff profitable to the users all over Europe** (EU Directive) - **New financial instruments** - **R&D programmes** - **Standardisation** (for training installers and installation procedures) - **BIPV Regulation** (mandatory to integrate PV into the building sector) - **Public awareness programmes** (training, information, education, etc.)
Stand-alone industrial application	2010	**Develop the market**	**Mobile telephone** **Traffic information systems**
Consumer application	2010	**Integrate PV into OEM products**	**Cooperation with the automotive industry**
Off-grid	2010	**Develop the market**	**Remote areas mainly in Southern Europe**

Source : EPIA


7.3 DEVELOPMENT OF EXPORT MARKETS

7.3.1 GENERAL REMARKS

Large areas of developing countries are not grid-connected and will never be connected for economic reasons. These areas still require reliable and cost effective electricity sources.

Although Japan does have an export assistance programme to assist its industry in developing new market opportunities, the primary focus of the Japanese PV programme is to develop domestic energy supply. Similarly the US in its industry roadmap framework[5] acknowledges the importance of the international market but fails to address the issue further. EPIA firmly believes that the developing country need and demand for improved energy services represents a major market opportunity for European renewable – and particularly PV – industry.

More than this though, PV offers the best approach for delivering cost-effective solutions to meet rapidly expanding developing country energy demand, while minimising the environmental impact of this demand. Delivering affordable modern energy services for health, education and social and economic development is central to international aid objectives. EPIA sees PV as a vital development tool, which can ultimately assist in alleviating rural, and trans-border migration and offsetting energy supply contention.

Developing country PV market assistance therefore has real potential for assisting economic and political stability, with clear implications for improved international security. It should also be emphasised that a robust demand in less developed countries can make an important contribution to the overall cost-reduction process for PV technology.

The massive export potential of the PV industry can be a main driver for the European industry base. The goal for European industry should be to capture a 40% market share of the annual 550 MWp market expected in 2010.

Increasing the quality of life of the rural poor fits in well with the EU International Development Objectives. Thus there is strong justification for export assistance. Dedicated subsidies for product development for this market and a revolving fund specifically for rural PV systems would also be of use. For example this could assist local capacity building for installation and maintenance, including credit schemes. Additionally this export framework must include better co-operation between EU and national level export promotion agencies and the mobilisation of funds available to the Export Credit Agencies (ECAs).

[5] Report of the US Photovoltaics Industry Technology Roadmap Workshop, June 23-25, 1999

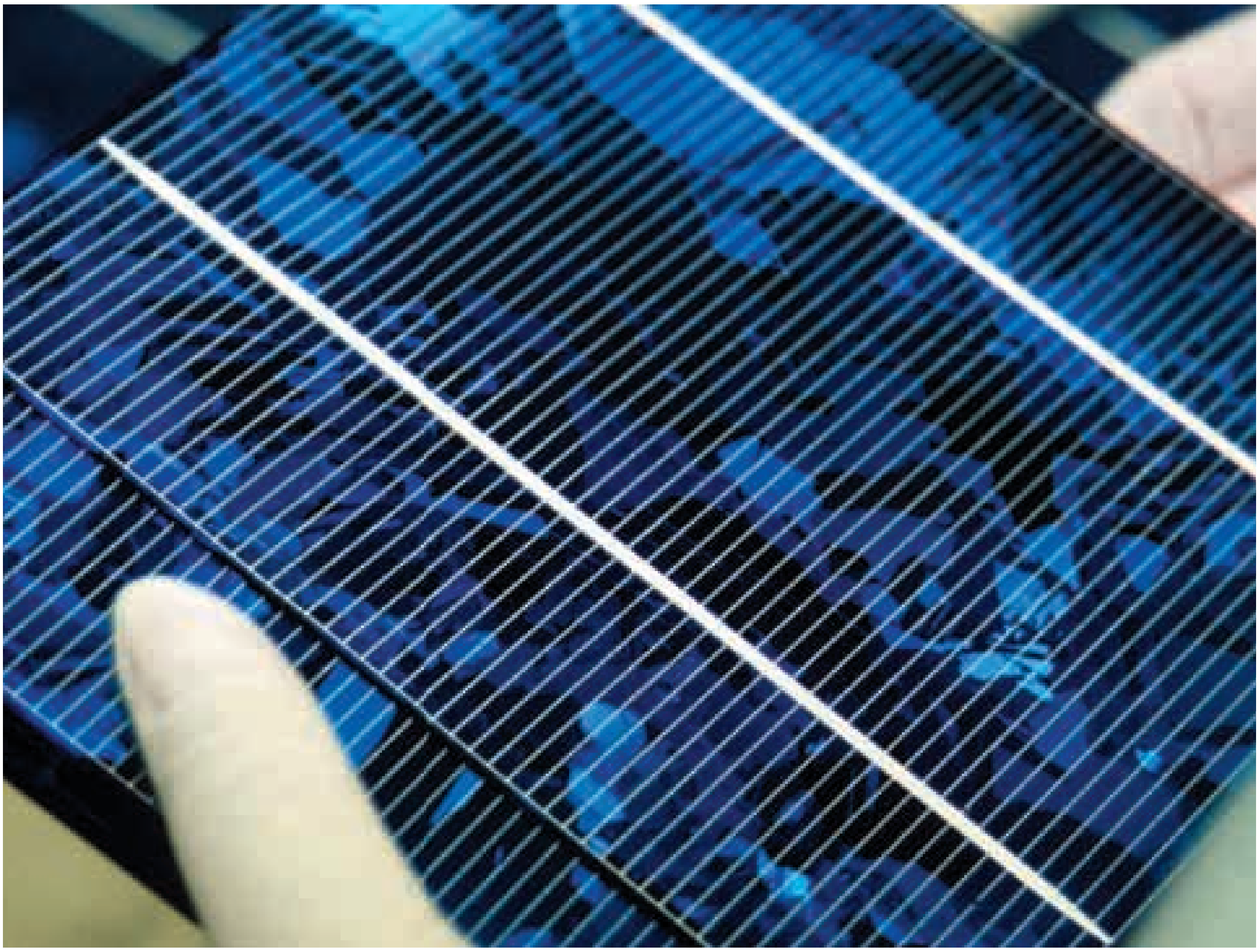
7.3.2 ACTION PLAN

The following tables list the proposed actions (examples), targets and milestones, the specific efforts and the actors addressed:

MILESTONES FOR EPIA ROADMAP: Export Markets

Topic	Time	Goals	Action Items/Actors
Developing countries	2010 (2020)	**1 GWp** (cumulative and for the EU Industry systems installation) **30 GWp** (cumulative and for the EU Industry systems installation)	**National, European and International programmes adapted to specific regions** (200 Mio. € per region) for multiplying effect contribution. **Establishment of financing scheme for affordable consumer payment.** **EU RES agencies into specific regions** **Supply of complete systems for water, communication, refrigeration, cooling, lighting, etc.** **Accompanying measures** (training, education, etc.) **Replication to other areas with an objective of 1 billion people served.**
Other OECD countries	2010 to 2020	**20% of installed PV power**	**EU Industry competitiveness** **EU export agency and relevant representation in the OECD countries**

Source : EPIA



8 STRATEGIC ACTIONS FOR ESTABLISHING A VITAL AND SUSTAINABLE PV INDUSTRY

EPIA has devised a programme of specific actions that European industry, in consort with other key stakeholders from policy, finance, electricity industry, academia, construction and other sectors should adopt in order that Europe may capitalise on the global PV market potential. Central to the programme are the following three branches of policy support which provide the long-term framework for industry to base its investments upon.

- A European rate-based incentive scheme (feed-in tariff). Using the German model to support grid-connected PV, there should be a guaranteed price paid through utilities for PV generated electricity of x Euro/kWh, guaranteed for y subsequent years. x and y should be chosen in such a way in order to cover the cost for investment, maintenance, repair and financing. For example in Germany for roof integrated systems x is currently 0, 57 Euro/kWh and y = 20 years. During the lifetime of the scheme the guaranteed feed-in tariff could fall each year for new contracts, in order to encourage PV manufacturers to strive for continued cost reductions. In Germany this is currently 5% p.a. This model should consider the solar radiation in each member state in such a way that the owner of the PV systems can operate it economically.
- Continued focused RTD Programme with improved funding arrangements: Extensive research and technological development is essential for the European PV industry to remain competitive and to open up new markets. Improved co-operation between the research sector and industry will help the research sector to better understand the needs of the PV industry and its customers, and the development of more suitable technologies. So there must be better focusing by the European research institutes, by channelling a larger share of public funds through industry. In the medium term 70% of research funds should be allocated to industry, half for in-house research and half reallocated to research institutes. Research will concentrate on the key areas described earlier.
- Export promotions assistance. To promote exports of European technology, particularly to the rural electrification market in developing countries, EPIA recommends the installation or expansion of trade houses in important receiving countries, and a European central clearing office to answer exporters' questions. There should also be dedicated subsidies for product development for this market and a revolving fund specifically for rural PV systems.

As Germany's and Japan's experiences have so clearly demonstrated, a stable and supportive policy framework, backed by a coherent programme of research and technological development is central to securing industry investment and maximising market development potential and market share. EPIA believes that a cohesive European policy environment and clearly focused RTD programme established for a minimum of 8-10 years, coupled with a strong export focus is vital if Europe is to maximise the benefits of this promising industry.

With these measures in place, the target of 3 GWp installed in Europe by 2010 is realistic and possibly could reach 5 GWp. Moreover EPIA's plan will strongly increase competitiveness of European PV-industry and, in the longer-term, deliver solar electricity at economic prices.

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