> Competitiveness

Solar Generation V – 2008

Solar electricity for over one billion people and two million jobs by 2020

GREENPEACE

EPIA
European Photovoltaic Industry Association

Contents

In 2001, for the first time, EPIA and Greenpeace joined forces with a mission in telling a broad audience of the latest developments and future potentials of Photovoltaics. Thus, **Solar Generation** was born.

7 years and 5 editions later, 7 GW of PV capacity more, tens of thousands of PV jobs created, hundreds of companies founded, many TWh of electricity produced and millions of tons of CO_2 saved; PV is facing a different world. Nobody, not even the optimistic PV industry thought back in 2001 that only a few years later more than 2 GW, almost 10 times more than in 2001, would be installed in only one year.

Last year's Foreword to Solar Generation highlighted that a unique window of opportunity for PV was opened. Scientific reports (Stern Report, IPCC Report) and political activities (2020 Energy targets of the European Union) have driven a public awareness all over the world that the time has come, ultimately, for action in order to save the planet from the consequences of climate change.

Foreword

In 2008, as also during the years before, EPIA and Greenpeace had to update their scenarios in order to keep pace with the dynamic PV development. The global energy situation has changed even more drastically in just one year. If last year a window of opportunity for PV was opened; this year the entire front wall of the house has been torn down. The opportunity for action has not only become huge, it has become an economic necessity!

Energy prices are skyrocketing. Energy is becoming more and more unaffordable for more and more people all over the world. The global PV capacities have to grow faster and they can grow faster as Solar Generation V will show. The global PV industry is willing to take the challenge.

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President European Photovoltaic Industry Association (EPIA)

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Executive Summary

Global Status of Solar Photovoltaics

The solar electricity market is booming. By the end of 2007, the cumulative installed capacity of solar photovoltaic (PV) systems around the world had reached more than 9,200 MW. This compares with a figure of 1,200 MW at the end of 2000. Installations of PV cells and modules around the world have been growing at an average annual rate of more than 35% since 1998.

Such has been the growth in the solar electricity industry that it is now worth more than an annual € 13 billion.

Competition among the major manufacturers has become increasingly intense, with new players entering the market as the potential for PV opens up. The worldwide photovoltaics industry, particularly in Europe, the USA, China and Japan, is investing heavily in new production facilities and technologies. At the same time, political support for the development of solar electricity has led to far-reaching promotional frameworks being put in place in a number of countries, notably Germany, Spain, Italy, France, South Korea, USA, etc.

Since the first edition of Solar Generation was published in 2001, the global PV market has continued to expand at more than the rate then predicted (see table below). Although in some countries progress has been slower than expected, others have exceeded expectations. The German market in particular has consistently performed at the upper limit of its projected expansion rate. Other countries outside the OECD nations are also showing their determination to develop a solar-powered future.

This clear commercial and political commitment to the expansion of the PV industry means that the current surge of activity in the solar electricity sector represents merely a foretaste of the massive transformation and expansion expected to occur over the coming decades. The target: the realisation of a common goal of substantially increasing the penetration of solar electricity into the global energy mix, whilst also cutting greenhouse gas emissions.

Much work still needs to be done to turn potential into reality. One crucial step is to bring a far broader range of actors into the sector, particularly in the investment, finance, marketing and retail areas. At the same time, there is a need to transmit to as wide an audience as possible, the message that solar electricity will bring socio-economic, industrial and environmental benefits to regions which proactively encourage its uptake.

Solar Generation: A Projection to 2030

Numerous qualitative analyses about the potential market development of solar photovoltaics have been published in the past. The aim here has been to compile a detailed quantitative knowledge base, coupled with clearly defined and realistic assumptions from which extrapolations could be made on the likely development of the solar electricity market up to 2030 and beyond.

Taking its lead from success stories like those in Germany or Spain, this EPIA/Greenpeace report looks forward to what solar power could achieve - given the right market conditions and an anticipated fall in costs – over the first three decades of the twenty-first century. As well as projections for installed capacity and energy output, it makes assessments of the level of investment required, the number of jobs which would be created, and the crucial effect which an increased input from solar electricity will have on greenhouse gas emissions.

Annual MW Installations Capacity:
Market versus 'Solar Generation' Scenario Predictions since 2001

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Market Result	334	439	594	1,052	1,320	1,467	2,392			
SG I 2001 MW	331	408	518	659	838	1,060	1,340	1,700	2,150	2,810
SG II 2004 MW					985	1,283	1,675	2,190	2,877	3,634
SG III 2006 MW						1,883	2,540	3,420	4,630	5,550
SG IV 2007 MW							2,179	3,129	4,339	5,650
SG V 2008 MW								4,175	5,160	6,950

This scenario for the year 2030, is based on the following core inputs:

- **PV market development over recent years, both globally and in specific regions**
- **National and regional market support programmes**
- **National targets for PV installations and manufacturing capacity**
- **The potential for PV in terms of solar irradiation, the availability of suitable roof space and the demand for electricity in areas not connected to the grid**

The following assumptions have been employed:

Global electricity consumption: Two different assumptions are made for the expected growth in electricity demand. The reference version is based on the International Energy Agency's latest World Energy Outlook (WEO 2007). An alternative version is based on the Greenpeace/European Renewable Energy Council Energy [R]evolution Report, which assumes extensive energy efficiency measures. The PV contribution is therefore higher under this projection.

Carbon dioxide savings: Over the whole scenario period, it is estimated that an average of 0.6 kg of CO_2 would be saved per kilowatt hour of output from a solar generator.

There are two versions of the scenario: an ***Advanced Scenario*** based on the assumption that additional support mechanisms will lead to dynamic worldwide growth; a ***Moderate Scenario*** which assumes a continuing but lower level of political commitment. The growth rates assumed in these scenarios vary from 40% reducing to 15% over the scenario period (2030) under the *Advanced version*, 30% reducing to 10% under the *Moderate version*.

The two scenario versions are also divided in two ways – into the four main global market divisions (consumer applications, grid-connected, remote industrial and off-grid rural), and into the regions of the world as defined in projections of future electricity demand made by the International Energy Agency.

Solar Generation: Key Results of the EPIA/ Greenpeace Analysis

The key results of the EPIA/Greenpeace scenario clearly show that, even from a relatively low baseline, solar electricity has the potential to make a major contribution to both future global electricity supply and the mitigation of climate change. The figures below are for the *Advanced Scenario*:

Global Solar Electricity Output in 2030
8.9 % of global electricity demand from PV – demand forecast from IEA Reference Scenario
13.8 % of global electricity demand from PV – demand forecast from the Greenpeace Energy [R]evolution Scenario

Detailed Projections for 2030	
PV systems cumulative capacity	1,864 GW
Electricity production	2,646 TWh
Grid-connected consumers	1,280 million
Off-grid consumers	3,216 million
Employment potential	10 million jobs
Market value	€ 454 billion per annum
Cost of solar electricity	€ 7-13 per kWh depending on location
Cumulative CO_2 savings	8,953 million tonnes of CO_2

Solar Generation: PV's Contribution to Global Electricity Supply

The EPIA/Greenpeace Advanced Scenario shows that by the year 2030, PV systems could be generating approximately 2,600 TWh of electricity around the world. This means that, assuming a serious commitment is made to energy efficiency, enough solar power would be produced globally in twenty-five years' time to satisfy the electricity needs of almost 14% of the world's population.

The capacity of annually installed solar power systems would reach 281 GW by 2030. About 60% of this would be in the grid-connected market, mainly in industrialised countries. The total number of people by then covering their own electricity from a grid-connected solar system would reach 1,280 million.

Although the key markets are currently located mainly in the industrialised world, a global shift will result in a significant share – about 20% or an annual market of 56 GW – being taken by the developing world for rural electrification in 2030. Since system sizes are much smaller, and the population density greater, this means that up to 3.2 billion people in developing countries would by then be using solar electricity. This would represent a major breakthrough for the technology from its present emerging status.

Solar Generation: PV's Contribution to Industry, Employment and the Environment

As the annual PV market could grow to 281 GW, the PV industry is facing great chances. For the job seekers of the third decade of the 21st century, there would be a major contribution towards their employment prospects. On the assumption that more jobs are created in the installation and servicing of PV systems than in their manufacture, the result is that by 2030, around 10 million full-time jobs would have been created by the development of solar power around the world. The majority of those would be in installation and marketing.

By 2030, solar PV would also have had one other important effect. In environmental terms, it would be reducing annual CO_2 emissions by 1.6 billion t. This reduction is equivalent to the output from 450 coal-fired power plants. Cumulative CO_2 savings from solar electricity generation would have reached a level of 9 billion t.

Policy Recommendations

In order to supply more than 3 billion people with solar electricity by the year 2030, a major shift in energy policy will be needed. Experience over the past few years has demonstrated the effectiveness of joint industrial and political commitment to achieving greater penetration of solar electricity into the energy mix at local, national, regional and global levels.

A number of key political actions are required:

- **Firstly, growth of the world annual PV market to a level of 281 GW by 2030 will only be achieved through the extension of best-practice support schemes, appropriately adapted to local circumstances, to encourage the uptake of solar electricity amongst consumers. The German and Japanese experiences highlight the impact which such actions can have. In Europe, the feed-in tariff has proved to be the most effective market support mechanism for renewable energy, including solar PV.**
- **Secondly, the inherent barriers to the take-up of solar power - and the subsidies available to fossil and nuclear fuels which currently penalise renewable sources - must be removed.**
- **Thirdly, a variety of legally-enforced mechanisms must be implemented which secure and accelerate the new market for solar photovoltaics.**

Our goal now must be to mobilise the necessary industrial, political and end-user commitment to this technology and, more importantly, the services it provides. We must redouble our efforts to ensure that the generation born today benefits from all the socio-economic and environmental benefits that solar electricity offers.

What is the difference between solar thermal collectors and a photovoltaic power system?

Solar thermal collectors are used to heat water, mainly for household use. Photovoltaic systems generate electricity.

What is the difference between grid-connected and off-grid?

Grid-connected applications can feed electricity directly into an electricity network. Off-grid systems often have batteries to store the electricity produced and have no access to the electricity grid.

Do we have enough silicon as raw material?

The raw material silicon used in the PV industry is abundantly available worldwide. However, the process of producing the pure silicon needed for crystalline solar cells is complex. It can take two years from planning a new silicon factory to its first output. The dynamic development of the PV market has led to a shortage of pure silicon, and the industry has reacted by building new capacity. These new factories improve the supply situation.

Is it possible to recycle photovoltaic modules?

Yes, all components in a solar module can be recycled. The most valuable parts are the solar cells themselves, which can be recycled into new wafers as the basis for new solar cells. The aluminum frames, glass and cables can also be recycled. For more information: **www.pvcycle.org**

When will PV be cost-competitive?

In many cases solar electricity is already cost-competitive, especially for stand-alone applications where no access to the public grid is available. In southern Europe, grid-connected photovoltaic electricity will be cost-competitive with peak power by 2015. PV prices are expected to continue to fall.

Do PV systems generate more energy over their lifetime than is needed for their production?

Yes. After approximately two years, a PV system in southern Europe based on crystalline technology will have generated as much energy as was needed to produce and install all its components. For a thin film system, the period is about a year. Over a PV system's lifetime of more than 30 years, it will produce far more energy than was used to create it. The energy used in PV production is continually being reduced.

Is PV only efficient in southern countries?

No. PV works everywhere where there is light. Even in southern Germany, an average sized roof-top system of 3 kW generates close to 3,000 kWh annually. This could cover the annual total electricity demand of a single household.

Is PV expensive?

The electricity generation costs for PV systems are currently higher than for other energy sources, if the environmental costs of conventional electricity generation are excluded. Financial support is therefore needed to develop a strong industry with economies of scale. With large-scale production, prices are expected to fall below residential electricity prices and will also compete with the generation costs of all other electricity sources (nuclear, fossil) within 20-30 years. In countries with feed-in tariffs, PV is already a very attractive investment.

Is there enough space to install a large number of PV systems?

Yes. PV is a space-efficient technology. For a 1 kW system about 7 m^2 of modules are necessary. In order to cover the entire electricity demand of the EU, only 0.7% of the total land area would be needed. There is a huge area available which is not competing with other land uses, including roofs, building façades, noise barriers and vacant plots. Space availability is not a limiting factor for PV development.

How long is the lifetime of a PV module?

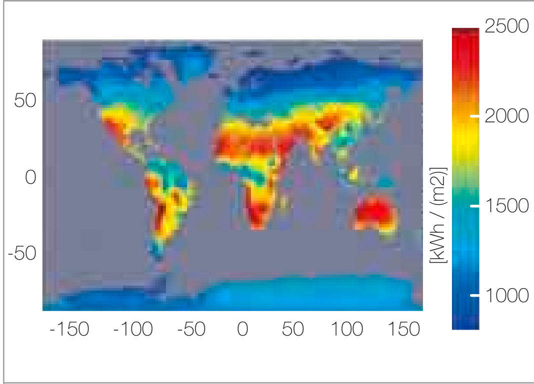
Many producers give performance warranties of 20-25 years for their modules. At the EC Joint Research Centre in Ispra (Italy), crystalline modules have been operating in a field test, with excellent performance results, for more than 20 years. The majority of the modules continue to exceed 92% of their nominal power output as recorded at the beginning of the testing period.

How much space do you need to install a roof-top system?

This depends on the technology used. A 3 kW system based on crystalline modules needs about 23 m^2 of a sloped roof area facing approximately south.

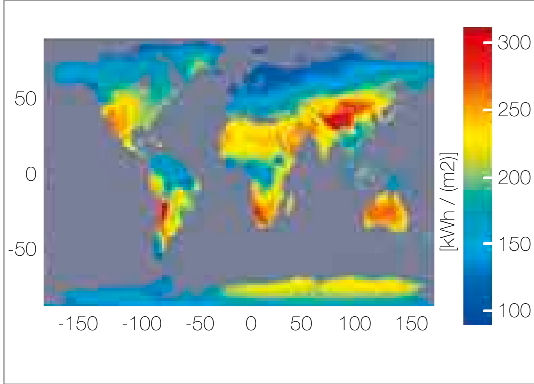
Part One:
Solar Basics

Figure 1.1: Global variations in irradiation



Source: Gregor Czisch, ISET, Kassel, Germany

Figure 1.2: Energy potential from PV around the world



Source: Gregor Czisch, ISET, Kassel, Germany

The solar potential

There is more than enough solar radiation available around the world to satisfy the demand for solar power systems. The proportion of the sun's rays that reaches the earth's surface can satisfy global energy consumption 10,000 times over. On average, each square metre of land is exposed to enough sunlight to receive 1,700 kWh of energy every year.

The statistical information base for the solar energy resource is very solid. The US National Solar Radiation database, for example, has logged 30 years of solar radiation and supplementary meteorological data from 237 sites in the USA. European solar radiation data from 566 sites is published and assessed by the European Joint Research Centre (JRC) (http://re.jrc.ec.europa.eu/pvgis).

The greater the available solar resource at a given location, the larger the quantity of electricity generated. Subtropical regions offer a better resource than more temperate latitudes. The average energy received in Europe is about 1,000 kWh per square metre per year, for example. This compares with 1,800 kWh in the Middle East.

Figure 1.2 shows the estimated potential energy output from solar PV generators in different parts of the world. The calculation takes into account the average efficiency of modules and converters, as well as the correct angle to the sun required at different latitudes.

A comparison between *Figures 1.1* and *1.2* shows that only a certain part of solar radiation can be used to generate electricity. However, unlike with conventional energy sources, there is no waste of energy through efficiency losses, as sunlight cannot be wasted. It has been calculated that if 0.71% of the European land mass was covered with PV modules, this would meet Europe's entire electricity consumption. Furthermore, International Energy Agency (IEA) calculations show that if only 4% of the world's very dry desert areas were used for PV installations, this would meet the whole world's total primary energy demand. Considering the vast areas of unused space (roofs, building surfaces, fallow land, deserts etc) the potential is almost inexhaustible.

New Isofotón factory in Malaga

© Isofotón

What is photovoltaic energy?

'Photovoltaic' is a marriage of two words: 'photo', meaning light, and 'voltaic', meaning electricity. Photovoltaic technology, the term used to describe the hardware that converts solar energy into usable power, generates electricity from light.

At the heart of photovoltaic (PV) technology is a semi-conductor material which can be adapted to release electrons, the negatively charged particles that form the basis of electricity. The most common semi-conductor material used in photovoltaic cells is silicon, an element most commonly found in sand. There is no limitation to its availability as a raw material; silicon is the second most abundant material in the earth's mass.

All PV cells have two layers of semi-conductors, one positively charged and one negatively charged. When light shines on the semi-conductor, the electric field across the junction between these two layers causes electricity to flow, generating DC (direct current). The greater the intensity of the light, the greater the flow of electricity.

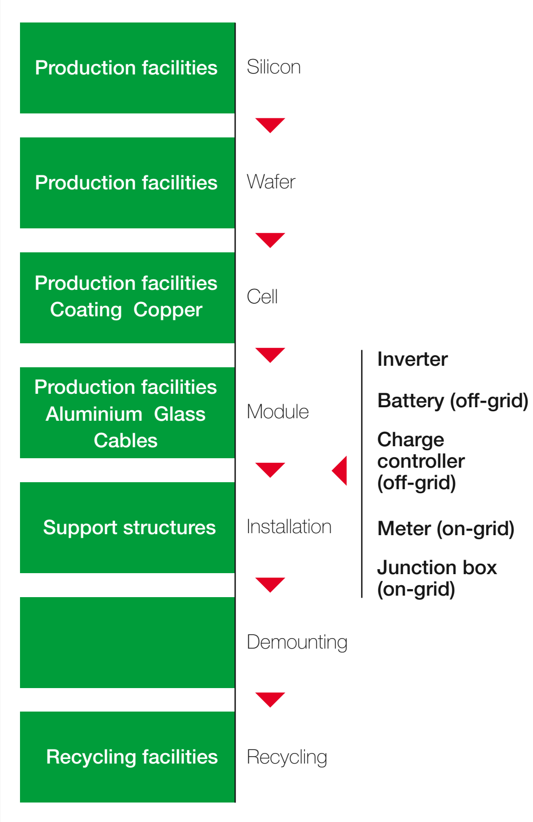
A photovoltaic system therefore does not need bright sunlight in order to operate. It can also generate electricity on cloudy days. Due to the reflection of sunlight, days with slight cloud can even result in higher energy yields than days with a completely cloudless sky.

Generating energy through solar PV is quite different from how a solar thermal system works, where the sun's rays are used to generate heat, usually for hot water in a house, swimming pool etc.

The advantages of PV technology:

- **The fuel is free.**
- **There are no moving parts to wear out, break down or replace.**
- **Only minimal maintenance is required to keep the system running.**
- **The systems are modular and can be quickly installed anywhere.**
- **It produces no noise, harmful emissions or polluting gases.**

Figure 1.3: Lifecycle of a PV system (c-Si)



PV technology

The most important parts of a PV system are the **cells** which form the basic building blocks of the unit, collecting the sun's light, the **modules** which bring together large numbers of cells into a unit, and, in some situations, the **inverters** used to convert the electricity generated into a form suitable for everyday use.

PV cells and modules

PV cells are generally made either from **crystalline silicon**, sliced from ingots or castings or from grown ribbons, or **thin film**, deposited in thin layers on a low-cost backing. Most cell production (90% in 2007) has so far involved the former, whilst future plans have a strong focus on the latter. Thin film technology based on silicon and other materials is expected to gain a much larger share of the PV market. This technology offers several advantages, such as low material consumption, low weight and a smooth appearance.

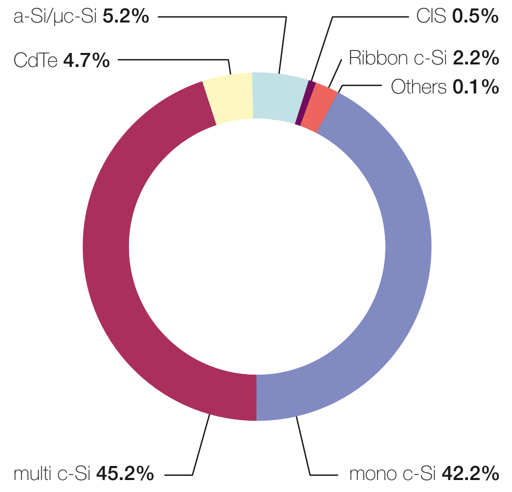
Crystalline silicon

Crystalline silicon is still the mainstay of most PV modules. Although in some technical parameters it is not the ideal material for solar cells, it has the benefit of being widely available, well understood and uses the same technology developed for the electronics industry. Efficiencies of more than 20% have been obtained with silicon cells already in mass production. This means that 20% of the incoming insolation can be transferred into electricity.

As well as the efficiency of the solar cells, their thickness is also an important factor. Wafers - very thin slices of silicon - are the basis for crystalline solar cells. Thinner wafers mean less silicon needed per solar cell and therefore lower cost. The average thickness of wafers has been reduced from 0.32 mm in 2003 to 0.17 mm in 2008. Over the same period, the average efficiency has increased from 14% to 16%. By 2010, the aim is to reduce wafer thickness to 0.15 mm whilst increasing efficiency to an average of 16.5%.

During wafer production, a significant amount of valuable silicon is lost as sawing slurry. Ribbon sheet technology represents an alternative approach. This avoids sawing loss by producing thin crystalline silicon layers using a range of techniques, such as pulling thin layers from the melt, or melting powdered silicon into a substrate. As sawing procedures, and the material losses linked to them, are avoided, the demand for silicon per watt of capacity can be reduced significantly.

Figure 1.4: Cell technology shares in 2007



Source: Photon International, March 2008

Large PV power plant with solar trackers located in Castejon, Spain

Thin film

Thin film modules are constructed by depositing extremely thin layers of photosensitive materials onto a low-cost backing such as glass, stainless steel or plastic. This results in lower production costs compared to the more material-intensive crystalline technology, a price advantage which is currently counterbalanced by substantially lower efficiency rates.

Three types of thin film modules are commercially available at the moment. These are manufactured from amorphous silicon (a-Si), copper indium diselenide (CIS, CIGS) and cadmium telluride (CdTe). All of these have active layers in the thickness range of less than a few microns. This allows higher automation once a certain production volume is reached, whilst a more integrated approach is possible in module construction. The process is less labour-intensive compared to the assembly of crystalline modules, where individual cells have to be interconnected.

A temporary shortage of silicon has also offered the opportunity for increasing the market share of thin film technologies. Several new companies are working on the development of thin film production based on a roll-to-roll approach. This means that a flexible

Table 1.1: Module and cell efficiencies

Technology	Thin Film				Crystalline wafer based	
	Amorphous silicon (a-si)	*Cadmium telluride (CdTe)*	*CI(G)S*	*a-Si/m-Si*	*Monocrystalline*	*Multicrystalline*
Cell Efficiency at STC*	5-7%	8-11%	7-11%	8%	16 –19%	14 – 15%
Module Efficiency					13 – 15%	12 – 14%
Area needed per kW (for modules)**	15 m^2	11 m^2	10 m^2	12 m^2	app. 7 m^2	app. 8 m^2

* Standard Testing Conditions: 25°C, light intensity of 1,000W/m^2, air mass = 1.5
** kW = kilowatt. Solar PV products and arrays are rated by the power they generate at Standard Testing Conditions

substrate, for example stainless steel, is coated with layers in a continuous process. The successful implementation of such a production method will offer opportunities for significantly higher throughput in the factory and lower costs. EPIA expects a growth in the thin film market share to reach about 20% of the total production of PV modules by 2010.

Among the three commercially available thin film technologies, a-Si is the most important in terms of production and installation, with 5.2% of the total market in 2007.

Multicrystalline thin film on glass (CSG) is a promising thin film technology which is now entering industrial production. Microcrystalline technology, in particular the combination of amorphous silicon and microcrystalline silicon (a-Si/m-Si), is another approach with encouraging results.

Other cell types

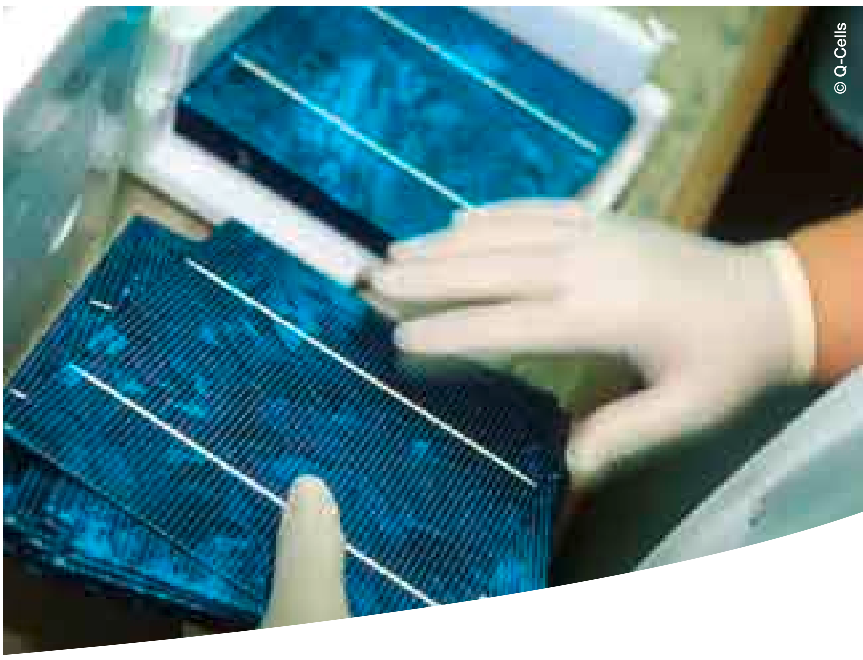
Concentrator cells work by focusing light on to a small area using an optic concentrator such as a Fresnel lens, with a concentrating ratio of up to 1,000. The small area can then be equipped with a material made from III-V compound semi-conductors (multi-junction Gallium Arsenide type), which have efficiencies of 30% and in laboratories of up to 40%. The two main drawbacks with concentrator systems are that they cannot make use of diffuse sunlight and must always be directed very precisely towards the sun with a tracking system.

Modules

Modules are clusters of PV cells incorporated into a unit, usually by soldering them together under a sheet of glass. They can be adapted in size to the proposed site, and quickly installed. They are also robust, reliable and weatherproof. Module producers usually guarantee a power output of 80% of the nominal power even after 20-25 years.

When a PV installation is described as having a capacity of 3 kW, this refers to the output of the system under standard testing conditions (STC), allowing comparisons between different modules. In central Europe, a 3 kW rated solar electricity system, with a module area of approximately 23 square metres (depending on technology, see *Table 1.1*), would produce enough power to meet the electricity demand of an energy-conscious household.

Multicrystalline cells at Q-Cells



Inverters

Inverters are used to convert the direct current (DC) power generated by a PV generator into alternating current (AC) compatible with the local electricity distribution network. This is essential for grid-connected PV systems. Inverters are offered in a wide range of power classes, from a few hundred watts through the most frequently used range of several kW (3-6 kW) up to central inverters for large-scale systems with 100 kW and above.

Components for stand-alone PV Systems

Stand-alone (off-grid) PV systems require a **battery**, frequently of the lead acid type, to store the energy for future use. New high-quality batteries designed especially for solar applications, with lifetimes of up to 15 years, are now available. However, the lifetime of the battery strongly depends on the battery management and the user's behaviour. The battery is connected to the PV array via a **charge controller**. The charge controller protects the battery from overcharging or discharging, and can also provide information about the state of the system or enable metering and pre-payment for the electricity used. If AC output is needed, an **inverter** is required to convert the DC power from the array.

New building at ECN with curved PV roof designed by BEAR architects: interior

Types of PV system

Grid-connected

This is the most popular type of solar PV system for homes and businesses in the developed world. Connection to the local electricity network allows any excess power produced to be sold to the utility. Electricity is then imported from the network outside daylight hours. An inverter is used to convert the DC power produced by the system to AC power for running normal electrical equipment.

In countries with a premium feed-in tariff, payment for the electricity generated (see *Part Six: Policy Drivers*) is considerably higher than the usual tariff paid by the customer to the utility, so all the electricity produced is often fed into the public grid and sold to the utility. This is the situation in countries such as Germany or Spain.

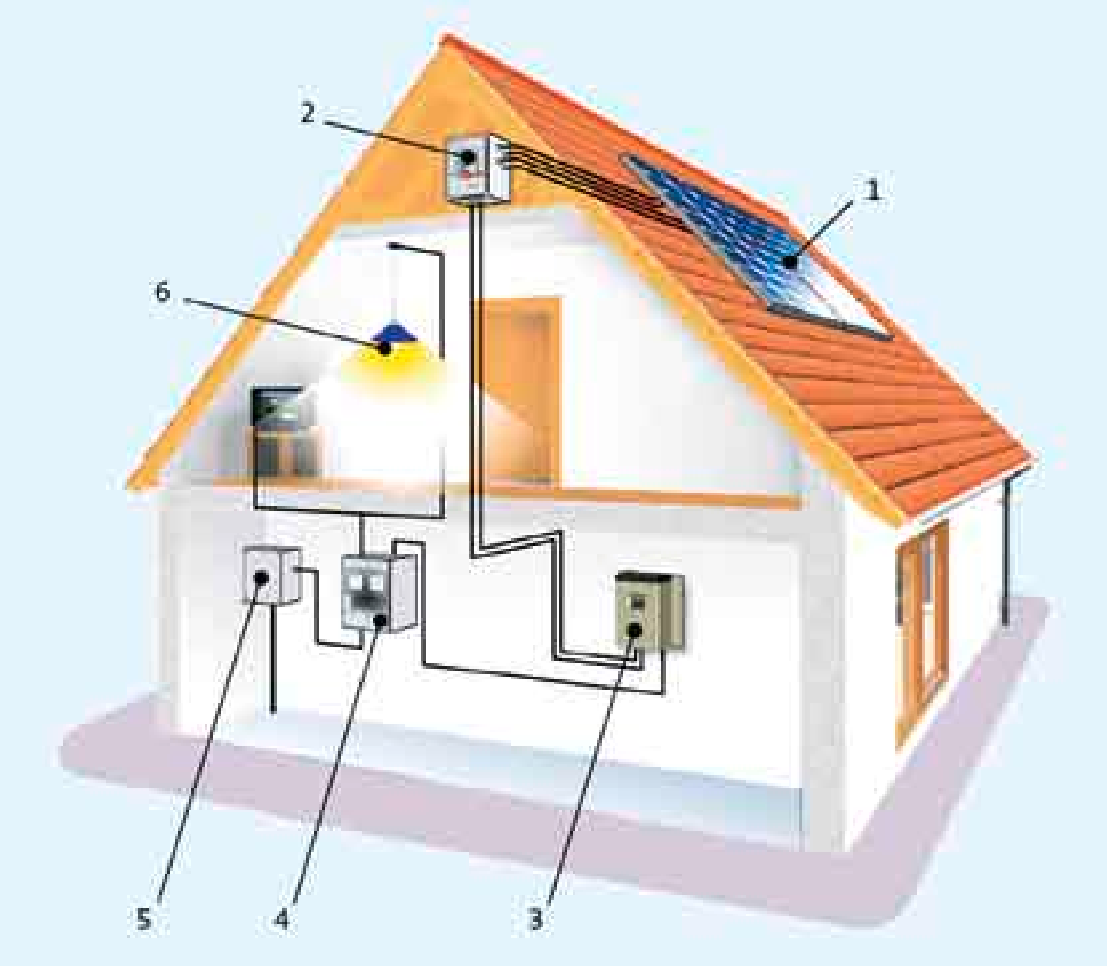
Off-grid

Where no mains electricity is available, the system is connected to a battery via a charge controller. This stores the electricity generated for future use and acts as the main power supply. An inverter can be used to provide AC power, enabling the use of normal electrical appliances. Typical off-grid applications are repeater stations for mobile phones, electrification for remote areas (mountain huts) or rural electrification in developing countries. Rural electrification means either small solar home systems covering basic electricity needs in a single household, or larger solar mini-grids, which provide enough power for several homes.

Hybrid system

A solar system can be combined with another source of power - a biomass generator, a wind turbine or diesel generator - to ensure a consistent supply of electricity. A hybrid system can be grid-connected, stand-alone or grid-support.

Figure 1.5: How a grid-connected photovoltaic system works



1 PV array 2 PV array combiner / junction box 3 Grid-tied inverter	4 Import / Export meter 5 Connection to the grid 6 Load

Figure 1.5 shows how electricity generated by solar cells in roof-mounted PV modules is transformed by an inverter into AC power suitable for export to the grid network.

The householder/generator then has two choices: either to sell all the output to the local power utility (if a feed-in tariff is available) or to use the solar electricity to meet demand in the house itself, and then sell any surplus to the utility.

Part Two:
The Solar Power Market

Solar power is booming. By the end of 2007, the cumulative installed capacity of all PV systems around the world had surpassed the landmark figure of 9,200 MW. This compares with a figure of 1,200 MW at the end of 2000. Installations of PV cells and modules around the world have been growing at an average annual rate of more than 35% since 1998.

The market value of the solar PV market reached an annual € 13 billion in 2007. Competition among the major manufacturers has become increasingly intense, with new players entering the market as the potential for PV opens up.

Although growth in recent years has been primarily in the grid-connected sector, the demand side of the international PV market can be clearly divided into four sectors. These market categories are used throughout this report.

Demand Side Market Sectors

1. Goods and services

Applications

Solar cells or modules are used in a wide range of consumer products and small electrical appliances, including watches, calculators and toys, as well as to provide power for services such as water sprinklers, road signs, lighting and phone boxes.

Large solar power plant in Spain

© Ecotecnia

Typical of new applications is the use of PV to control air conditioning in cars. A small system integrated in the roof keeps the temperature inside at a constant level by operating a ventilator when the car is parked, especially in the sun during summertime. This results in lower peak temperatures inside the car and a much cheaper air conditioning system, due to a lower requirement for power. Manufacturers may also be able to save on the cost of expensive heat-resistant materials in the vehicle's interior.

Market development

In 2007, this sector accounted for roughly 1% of global annual production. As demand for a mobile electricity supply increases, it is likely that the consumer goods market will continue to grow in absolute terms (although its relative share will decrease), especially with the introduction of innovative low-cost solar electricity technologies such as organic solar cells.

2. Grid-connected systems

Applications

PV applications which have a permanent connection to the electricity grid are categorised as on-grid applications. PV can be installed on top of a roof or integrated into the roofs and facades of houses, offices and public buildings. Private houses are a major growth area for roof systems as well as for Building Integrated PV (BIPV). A 3 kW solar electricity system in southern Germany delivers approximately 3,000 kWh/year, sufficient to supply up to 100% of the annual electricity needs of an energy-conscious household.

PV is also increasingly used as a design feature by architects, replacing elements in a building's envelope. Solar roof tiles or slates can replace conventional materials, flexible thin film modules can even be integrated into vaulted roofs, whilst semi-transparent modules allow for an interesting mixture of shading and daylight. PV can also be used to supply peak power to the building on hot summer days, when air conditioning systems need most energy, thus helping to reduce the maximum electricity load.

If a solar electricity system is recognised as an integral part of a building, then the money spent on decorative materials for facades, such as marble, can instead be invested in solar modules. Solar power doubles up as both an energy producer and a building material. For prominent businesses, it can provide the public face of their environmental commitment.

Distributed generation using solar facades or roofs can also provide benefits to a power utility by avoiding grid replacement or by strengthening and potentially reducing maximum demand for conventional electricity, especially in countries with a high cooling load. In particular, PV can soften the peak demand caused by the use of air conditioning systems. In many areas around the world, the extensive use of air conditioning during the summer months leads repeatedly to black outs and brown outs. Since supply from PV systems matches perfectly the demand from air conditioning systems. on bright, sunny days it can help to reduce the number of power cuts or reductions.

Large-scale grid-connected PV arrays (> 1 MW) represent about 10% of the European PV market. These systems are particularly suitable in areas where there is no competition from other land use demands. Such large plants function solely as power plants, and are therefore exclusively delivering electricity to the grid, without self-consumption. Sun-drenched desert regions present good opportunities in the longer term for large-scale plants, especially as module prices continue to fall, for instance in the south-west United States, Africa and Mongolia. In Germany, large-scale ground-based systems in the megawatt class have become a new market in recent years. This offers a fresh source of income for farmers, who can rent their land to investors, with the advantage of a secure revenue for at least 20 years.

Market development

This market segment is the current motor of the PV boom, with most development taking place in the OECD countries. More and more national governments see PV as an important technology for the future and have already established, or are in the process of establishing, support programmes. Whilst in 1994 only 20% of new PV capacity was grid-connected, this had grown to approximately 90% by 2007.

A growing number of countries have followed the successful examples of Germany, Japan and the USA, which have all established support programmes for grid-connected PV systems. These programmes will continue to provide an impetus for market growth for some years to come - until PV becomes competitive with domestic electricity prices (see *Part Six: Policy Drivers*).

Another substantial benefit of the grid-connected domestic market is the control which PV systems allow the consumer over their power supply. Not only is electricity generated at the point of demand, avoiding grid losses of electricity, but the consumer is effectively transformed into the operator of his or her own power station. As international power markets steadily liberalise, this is likely to have increasingly important market implications. The full effect will be visible as soon as PV gets close to achieving parity with domestic electricity prices.

3. Off-grid electrification

Applications

PV provides vital power for communities in the developing world who have no access to mains electricity. About 1.7 billion people around the world currently live without basic energy services. 80% of them live in rural areas. This huge market is a great opportunity for both the PV industry and the local population.

PV can provide electricity for both private consumption and industrial uses. Domestic energy systems provide high quality lighting and communications (radio/TV/internet), whilst energy used for cooling, water pumping or powering tools can be a crucial motor for local economic development. PV has the potential to deliver much more than just electricity for lighting or improved health care. By providing the

Installation of a PV system on a roof

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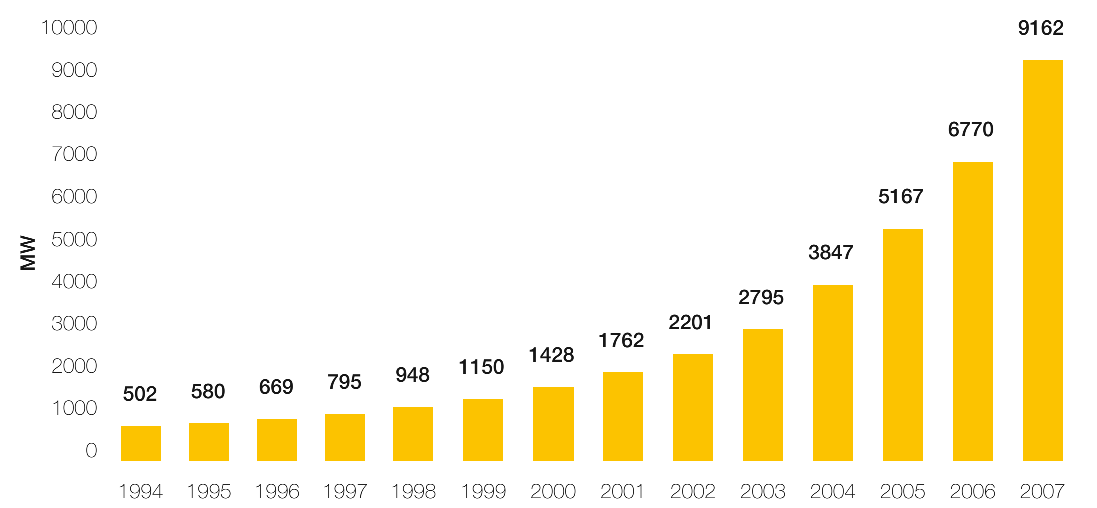
Figure 2.1: Global cumulative PV capacity



power supply for computers, for example, it can enable people to access better education or information through the internet.

There is also a powerful need to provide clean drinking water in the developing world. The World Health Organisation estimates that 10,000 children die each day from water-borne diseases. Solar-powered water purification systems and pumps are easily transportable, easy to maintain and simple to use and, as part of rural health initiatives, could be an important tool in the fight against disease.

PV systems integrated in the façade of a building

Market development

Apart from its clear social advantages, the economic justification for using PV is through the avoided fuel costs, usually expensive diesel, or by comparison with the cost of extending the grid. For subsistence-level communities, the initial stumbling block is often the capital cost of the system. Although numerous rural development programmes have been initiated in developing countries, supported both by multi- and bilateral assistance programmes, the impact has so far been relatively small. However, it is expected that this market segment will capture a substantial part of the global PV market share in the coming decades. In 2007, approximately 4% of global PV installations were dedicated to rural electrification.

4. Off-grid industrial

Applications

The most common industrial uses for off-grid solar power are in the telecommunications field, especially for linking remote rural areas to the rest of the country. In India, for example, more than a third of the PV capacity is devoted to the telecommunications sector. There is a vast potential for repeater stations for mobile phones powered by PV or PV/diesel hybrid systems.

Desalination plants are another important off-grid application for PV. Others include traffic signals, marine navigation aids, security phones, weather or pollution monitors, remote lighting, highway signs and wastewater treatment plants.

Figure 2.2: Global annual PV market

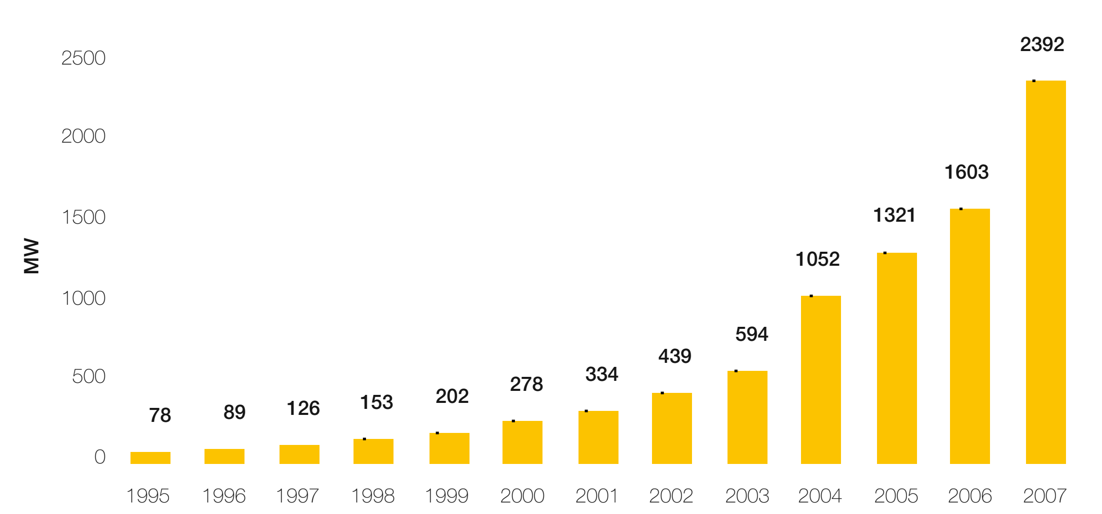
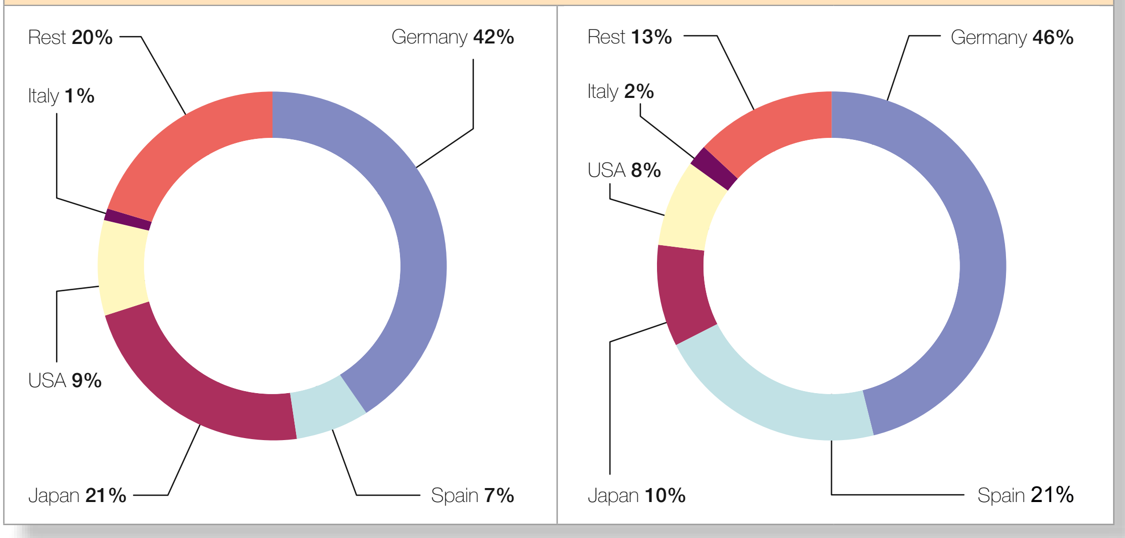


Figure 2.3: Top 5 PV country markets



Top 5 Total installed capacity 2007 (MW)		**Top 5 New capacity 2007 (MW)**	
Germany	3,800	Germany	1,100
Spain	632	Spain	512
Japan	1,938	Japan	230
USA	814	USA	190
Italy	100	Italy	50
		Rest	310

Market development

Apart from avoided fuel costs, by totally or partly replacing a diesel engine for example, industrial PV systems offer high reliability and minimal maintenance. This can dramatically reduce operation and maintenance costs, particularly in very remote or inaccessible locations.

The demand for off-grid industrial PV systems is expected to continue to expand over the next decade and beyond, especially in response to the continued growth of the telecommunications industry. Mobile telephone masts and repeater stations offer a particularly large potential, especially in countries with low population densities. Providing communications services to rural areas in developing countries as part of social and economic development packages, will also be a major future market opportunity for photovoltaics. About 4% of global PV installations were used for PV industrial off-grid applications in 2007.

Supply Side Market - Manufacture

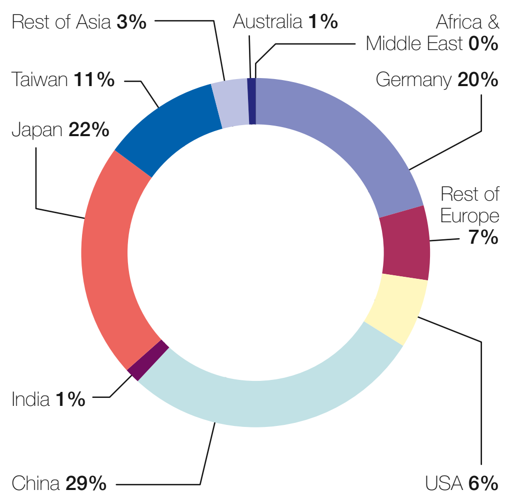
Solar grade silicon

Silicon is the basic material required for the production of solar cells based on crystalline technology – 90% of the world market. The availability of sufficient silicon at reasonable prices is therefore an essential precondition for a dynamic PV industry.

Until recently, the silicon industry produced electronic grade silicon exclusively for the semi-conductor industry, mainly for use in computers. Only a small fraction was delivered to the PV industry, which represented a good way for the suppliers to level out demand fluctuations from the semi-conductor industry. With the dynamic growth of the PV industry in recent years, however, the situation has changed. In 2007, more than half of the worldwide production of electronic grade silicon was used to produce solar cells.

This growing demand has motivated the silicon industry to change its approach. Silicon for solar cells can be of lower quality than that required for semi-conductors, and can thus be produced more cheaply. Several companies have therefore begun to develop processes for producing solar grade silicon. The development of these production lines and construction of the first factories will still take time, however. So, until all the new planned production facilities for solar grade silicon are operational, the PV industry will continue to compete with the semi-conductor industry for the currently limited supply available on the market.

Figure 2.4: Regional and national shares of global PV cell production in 2007



Source: Photon International – March 2008

It is expected that by 2008 the availability of solar grade silicon for the PV industry will lead to a much more relaxed situation in the silicon market. Between 2008 and 2010 it is projected that more than €4.1 billion will be invested in upscaling silicon production capacities.

Solar cell and module production

In 2008, the level of investment in new plants to manufacture solar cells and modules is expected to exceed €1.6 billion. This excludes wafer and silicon manufacturing capacities. This figure underlines the pace at which the PV industry is expanding in order to satisfy global demand.

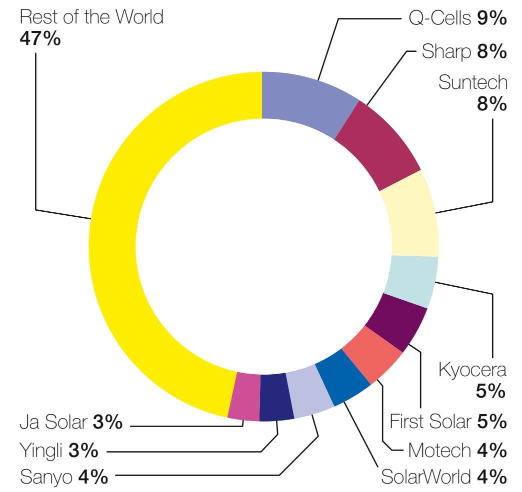
Aerial view of the German Parliament with PV modules integrated on the roof

Up to now, the manufacture of solar cells and modules has been concentrated in three key geographical areas – Europe, Japan and the United States. However, the country with the strongest growth in production facilities is China.

The leading cell production companies can be seen in *Figure 2.5*. Although until a few years ago the market was dominated by BP Solar, a subsidiary of the multinational oil company, this situation has radically changed with the entry of new Japanese and European players. More recently, the leading company in cell production has been the Japanese company Sharp. However, in 2007 Sharp has continued to lose market share relative to its competitors, in particular the German-based Q-Cells and Solarworld and the Chinese Suntech. These have together decreased the dominant position of Sharp from 23.6% in 2005 to 8.5% in 2007. In 2007 Q-Cells became the new market leader. Just over 53% of all cell production is handled by the 10 biggest companies (compared to 75 % in 2006); nearly all of these are currently investing heavily in new production facilities.

An important issue for manufacturers is being able to match the opening of new production capacity with expected demand. Investors need a planning horizon that goes beyond a typical factory's write-off period of five to seven years. Some smaller companies have nonetheless been able to obtain investment from public share ownership, often through one of the increasing number of green investment funds. This is why the relative stability of systems such as the German feed-in tariff, has proved crucial to business commitment. In anticipation of a flourishing market, Germany has seen a steady increase in both solar cell and module manufacture from 1995 onwards. Further encouraged by the Renewable Energy Law, updated in 2004, annual production of PV cells increased from 32 MW in 2001 to around 850 MW in 2007.

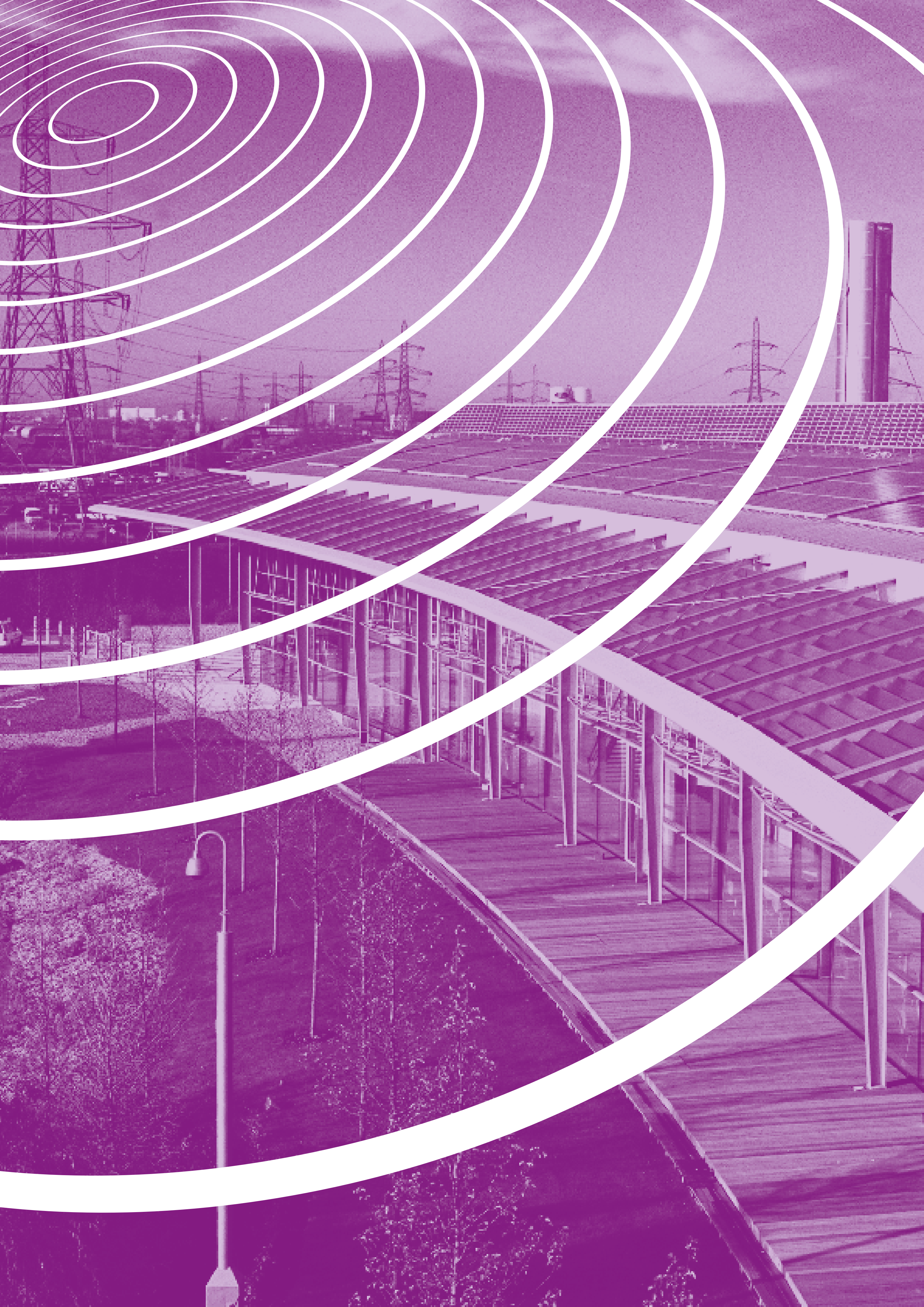
Figure 2.5: Top 10 PV cell producers



Source : Photon International

The higher up the PV value chain one travels, the fewer companies are involved. At the upper end of the chain, silicon production requires substantial know-how and investment, as does the production of wafers. At the level of cell and module producers, on the other hand, where know-how and investment needs are smaller, there are many more players in the market. At the end of the value chain, the installers are often small, locally-based businesses.

Installation of modules on a building roof



Part Three:
The Solar Future

The Greenpeace/EPIA 'Solar Generation' Scenarios

Methodology and Assumptions

If PV is to have a promising future as a major energy source, it must build on the experiences of those countries that have already led the way in stimulating the solar electricity market. In this section, we look forward to what solar power could achieve - given the right market conditions and an anticipated fall in costs - over the coming two decades of the twenty-first century. As well as projections for installed capacity and energy output, we also make assessments of the level of investment required, the number of jobs that would be created and the crucial effect that an increased input from solar electricity will have on greenhouse gas emissions (see Part Five: Solar Benefits).

PV Cell production process

The two EPIA /Greenpeace scenarios outlined below are based on the following core inputs:

- **Current PV market data from reliable sources (national governments, the International Energy Agency, PV industry)**
- **PV market development over recent years, both globally and in specific regions**
- **National and regional market support programmes**
- **National targets for PV installations and manufacturing capacity**
- **The potential for PV in terms of solar irradiation, the availability of suitable roof space and the demand for electricity in areas not connected to the grid**

1. Advanced Scenario

This scenario is based on the assumption that continuing and additional market support mechanisms will lead to a dynamic expansion of worldwide PV installed capacity. Market support programmes create economies of scale and PV prices will fall faster as a result, leading to a further market push. Although such market programmes are designed to be only a temporary means of support, they are nonetheless crucial in initiating a stable commercial environment. **EPIA/Greenpeace strongly believe that this scenario can be achieved if the necessary political support is forthcoming.**

Market growth rates under the *Advanced Scenario*	
Average growth rate 2007-2010	40%
Average growth rate 2011-2020	28%
Average growth rate 2021-2030	18%

2. Moderate Scenario

This scenario envisages the development of PV against the background of a lower level of political commitment. Over the longer term, the gap between the *Moderate* and *Advanced Scenarios* widens considerably. With insufficient additional global political support, fast market deployment is difficult. Without the potential for economies of scale, PV production costs and prices will fall at a slower rate than in the *Advanced Scenario*, resulting in a lower level of PV deployment.

Market growth rates under the *Moderate Scenario*	
Average growth rate 2007-2010	30%
Average growth rate 2011-2020	21%
Average growth rate 2021-2030	12%

The growth rates presented in the scenarios represent an average calculated from varying rates of annual growth.

The following assumptions have been employed to show the effect of these scenarios in terms of both electricity supply and carbon dioxide savings:

Electricity consumption

Two assumptions are made for the expected growth in electricity demand over the first decades of the 21^{st} century.

The *'Reference Scenario'* for growth in global electricity demand, against which the percentage contribution from PV power can be judged, is extracted from projections by the International Energy Agency (WEO 2007). These show global demand for power increasing from 15,016 TWh in 2005 to 21,278 TWh in 2015 and 29,737 TWh in 2030.

The *'Alternative Scenario'* for future electricity demand is based on the Greenpeace/European Renewable Energy Council Energy [R]evolution report (January 2007), and takes into account the extensive use of energy efficiency measures in order to decrease final electricity consumption. This scenario shows global demand for power increasing from 13,675 TWh in 2003 to 14,188 TWh in 2010, 16,614 TWh in 2020 and 19,189 TWh in 2030. The PV contribution is therefore higher under this projection.

Carbon dioxide savings

An off-grid solar system which replaces a typical diesel unit will save about 1 kg CO_2 per kilowatt hour of output. The amount of CO_2 saved by grid-connected PV systems depends on the existing profile of electricity production in different countries. The global average figure is taken as 0.6 kg CO_2 per kilowatt-hour. Over the whole scenario period, it has therefore been assumed that PV installations will save on average 0.6 kg CO_2 per kilowatt-hour.

The scenarios are also divided in two further ways - into the four global market divisions (consumer applications, grid-connected, off-grid industrial and off-grid rural), and into the regions of the world as defined in projections of future electricity demand made by the International Energy Agency. These regions are OECD Europe, OECD Pacific, OECD North America, Latin America, East Asia, South Asia, China, the Middle East, Africa and the Transition Economies (mainly the former Soviet Union).

Large solar power plant in Spain

Table 3.1: Solar Generation scenario results for global PV market up to 2030

	Current situation	Scenarios		
	2007	2010	2020	2030
Advanced Scenario				
Annual Installations in GW	2.4	6.9	56	281
Accumulated Capacity GW	9.2	25.4	278	1,864
Electricity Production in TWh	10	29	362	2,646
PV Contribution to electricity consumption - reference scenario (IEA)	0.07%	0.16%	2.05%	8.90%
PV Contribution to electricity consumption - alternative scenario	0.07%	0.20%	2.18%	13.79%
Grid connected people / households / people living on PV in Million	5.5	18	198	1,280
Off grid connected people in Million	14	32	757	3,216
Employment in thousand people	119	333	2,343	9,967
Market value in Billion €	13	30	139	454
Annual CO_2 savings in Mt	6	17	217	1,588
Cumulative carbon savings in Mt	27	65	976	8,953

Moderate Scenario				
Annual Installations in GW	2.4	5.3	35	105
Accumulated Capacity GW	9.2	21.6	211	912
Electricity Production in TWh	10	24	283	1,291
PV Contribution to electricity consumption - reference scenario (IEA)	0.07%	0.14%	1.20%	4.34%
PV Contribution to electricity consumption - alternative scenario	0.07%	0.17%	1.70%	6.73%
Grid connected people / households / people living on PV in Million	5,5	14	136	564
Off grid connected people in Million	14	59	837	2,023
Employment in thousand people	119	252	1,462	3,718
Market value in Billion €	13	24	94	204
Annual CO_2 savings in Mt	6	15	170	775
Cumulative carbon savings in Mt	27	61	839	5,333

Table 3.2: Solar Generation scenario: PV market development (annual installed capacity) up to 2010				
	2007	**2008**	**2009**	**2010**
Advanced Scenario	2,392 MW	4,175 MW	5,160 MW	6,950 MW
Moderate Scenario	2,392 MW	3,110 MW	4,043 MW	5,256 MW

Key results

The results of the Greenpeace/EPIA 'Solar Generation' scenarios show clearly that, even from a relatively low baseline, PV electricity has the potential to make a major contribution to both future electricity supply and the mitigation of climate change. The main figures can be seen in *Table 3.1* for the whole scenario period up to 2030, and the results for annual capacity up to 2010 only in *Table 3.2*.

The *Solar Generation Advanced Scenario* therefore shows that by 2030, PV systems could be generating approximately 2,646 terawatt hours of electricity around the world.

Under this scenario, the global installed capacity of solar power systems would reach 1,864 GW by 2030. About 74% of this would be in the grid-connected market, mainly in industrialised countries. The total number of people by then supplied with household electricity from a grid-connected (including building-integrated, large-scale and roof-top) solar system would reach approximately 1,280 million.

In Europe alone, there would be roughly 300 million people receiving their household electricity supply from grid-connected solar electricity. This calculation is based on an average household size of 2.5 people and an average annual electricity consumption of 3,800 kWh.

In the non-industrialised world, approximately 320 GW of solar capacity is expected to have been installed by 2030 for rural electrification. Here, the assumption is that, on average, a 100 Wp stand-alone system will currently cover the basic electricity needs of three people per dwelling. Over time, it is expected that larger systems will be used for rural electrification. However, system sizes in the developing world are presently much smaller than for on-grid applications in the developed word, and the population density is greater. **This means that up to 3.2 billion people in developing countries would by then be using solar electricity.** This would represent a major breakthrough for the technology from its present emerging status.

PV module production line

Figure 3.1: Global PV cumulative capacity up to 2030

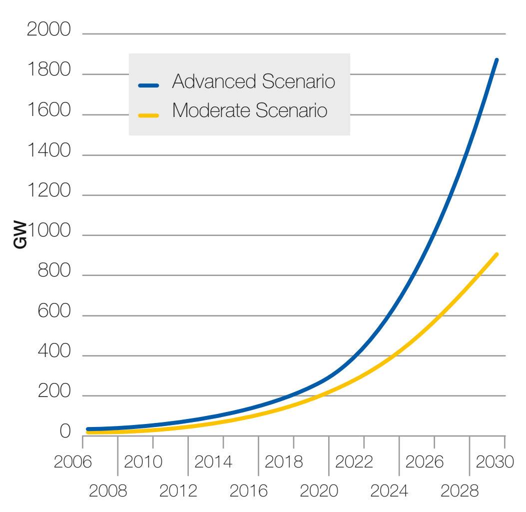


Figure 3.2: Global PV annual installed capacity up to 2030

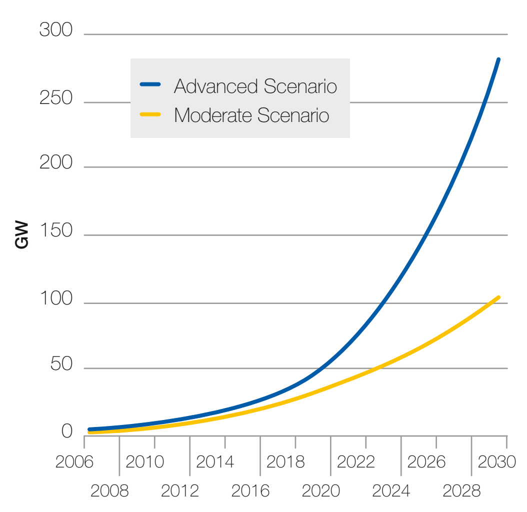
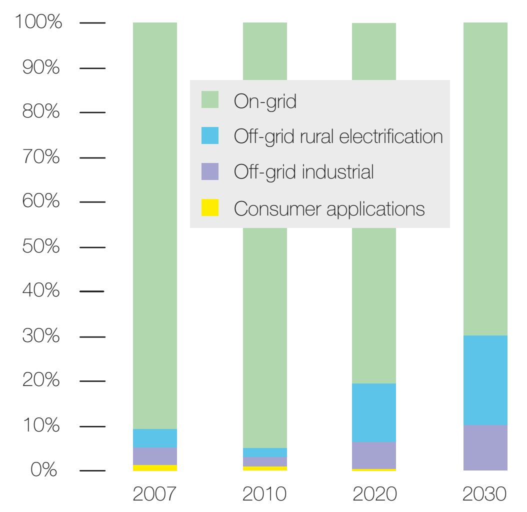


Figure 3.1 illustrates the development of cumulative installed PV capacity under the different scenarios. Until 2030 the projections differ considerably. The favorable Advanced Scenario is based on the positive development of PV from 2007-2015 highlighting the importance of political commitment in the upcoming years. Adequate support (see chapter: *Policy Drivers*) for PV in that period will therefore facilitate achieving the Advanced Scenario. An early enforcement of the dynamic development of mass production and cost reduction is necessary to establish PV as globally important energy source. *Figure 3.2* shows a similar development for annual PV installations.

Figure 3.3 illustrates the expected comparative development of the different types of PV application. All applications (on-grid, off-grid rural electrification, off-grid industrial and consumer applications) are expected to increase in absolute numbers (MW). However, the currently very dominant grid-connected sector, representing roughly 90% will on the long run loose share in favour of off-grid applications. Due to its immense potential, rural electrification in particular will experience considerable growth.

Figure 3.3: Annual PV installations by application



Figures 3.4 and *3.5* show how the Solar Generation scenarios break down in terms of the regions of the world. Annual installations *(Figure 3.4)* and cumulative capacities *(Figure 3.5)* are presented as a proportion of the actual market figure, depending on the scenario. In both cases, OECD Europe is the dominant region for PV deployment, followed by the OECD Pacific and OECD North America. Over time, it is expected that other regions of the world will gain share from the currently leading regions. By 2030, a globally diversified PV market can be expected where regions such as China and Africa will make a significant contribution.

Figure 3.4: Annual PV installations by regional share

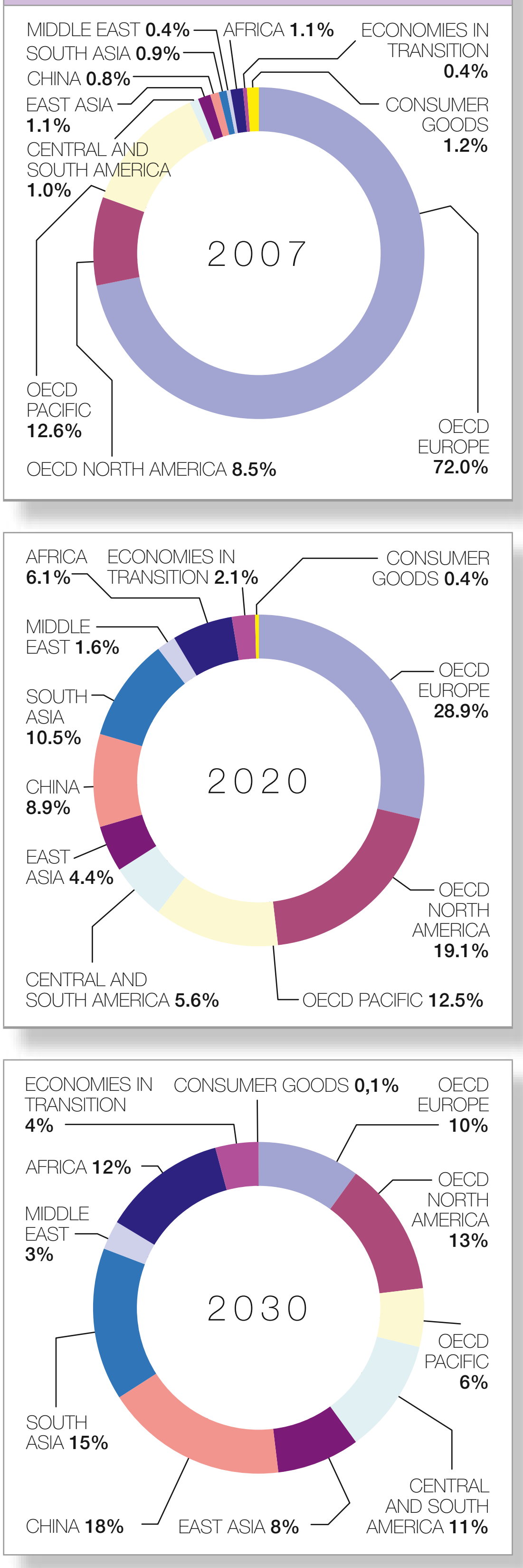


Figure 3.5: Cumulative PV installations by regional share

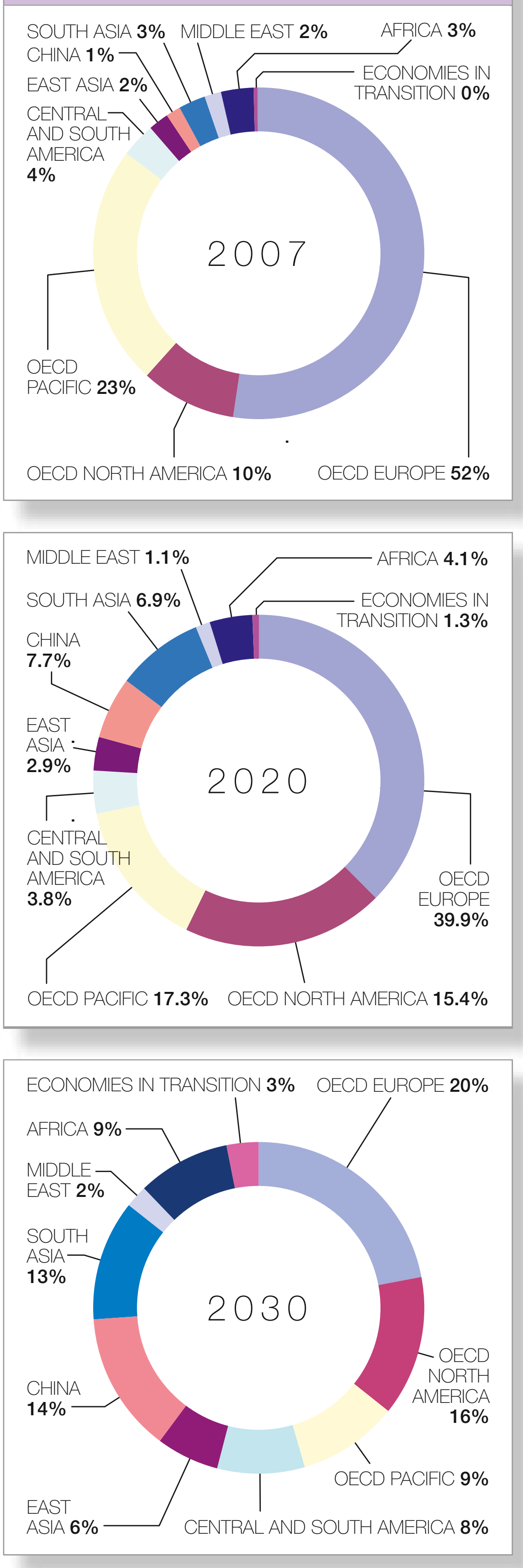


Table 3.3: Value of PV market (annually) up to 2030 under the *Advanced Scenario* (in million €)

Year	Europe	North America	OECD Pacific	Central and South America	East Asia	China	South Asia	Middle East	Africa	Economies in Transition	Total
2007	9,655	1,115	1,661	131	143	112	124	50	143	50	13,184
2010	11,610	6,199	4,582	338	370	432	1,762	129	370	129	25,919
2015	22,834	13,159	9,363	1,739	1,504	2,602	4,867	545	1,900	662	59,175
2020	40,342	26,612	17,425	7,831	6,069	12,434	14,580	2,246	8,547	2,894	138,980
2025	53,399	44,009	25,370	22,791	16,942	36,920	34,916	6,324	24,867	8,333	273,870
2030	45,433	59,062	27,260	49,976	36,346	81,779	68,149	13,630	54,519	18,173	454,325

Excluding consumer goods

Table 3.5: Investment in new production capacities under the *Advanced Scenario* (in million €)

	2008	2009	2010	Total
Silicon	930	1,615	1,556	4,100
Wafers	614	1,072	1,225	2,911
Cells	351	613	700	1,664
Modules	351	613	700	1,664
Thin Film	707	1,411	875	2,993
Total	2,952	5,323	5,056	13,332

Tables 3.3 and *3.4* calculate the projected market value of PV systems up to 2030 under respectively the *Advanced* and *Moderate scenarios*. This shows that by the end of the scenario period, the annual value of the PV market would have reached 454 billion Euros worldwide under the *Advanced Scenario* and 170 billion Euros under the *Moderate Scenario*.

Large PV power plant with thin film solar Modules

Table 3.4: Value of PV market (annually) up to 2030 under the *Moderate Scenario* (in million €)

Year	Europe	North America	OECD Pacific	Central and South America	East Asia	China	South Asia	Middle East	Africa	Economies in Transition	Total
2007	9,655	1,115	1,661	131	143	112	124	50	143	50	13,184
2010	12,355	4,924	3,640	268	294	344	1,400	102	294	102	23,723
2015	20,721	11,941	8,496	1,578	1,364	2,361	4,417	494	1,724	601	53,697
2020	27,189	17,936	11,744	5,278	4,090	8,380	9,826	1,202	5,761	1,950	93,355
2025	28,424	23,426	13,504	12,131	9,018	19,652	18,585	2,850	13,237	4,435	145,262
2030	17,008	22,111	10,205	18,709	13,607	30,615	25,512	5,102	20,410	6,803	170,081

Excluding consumer goods

Table 3.6: Investment in new production capacities under the *Moderate Scenario* (in million €)

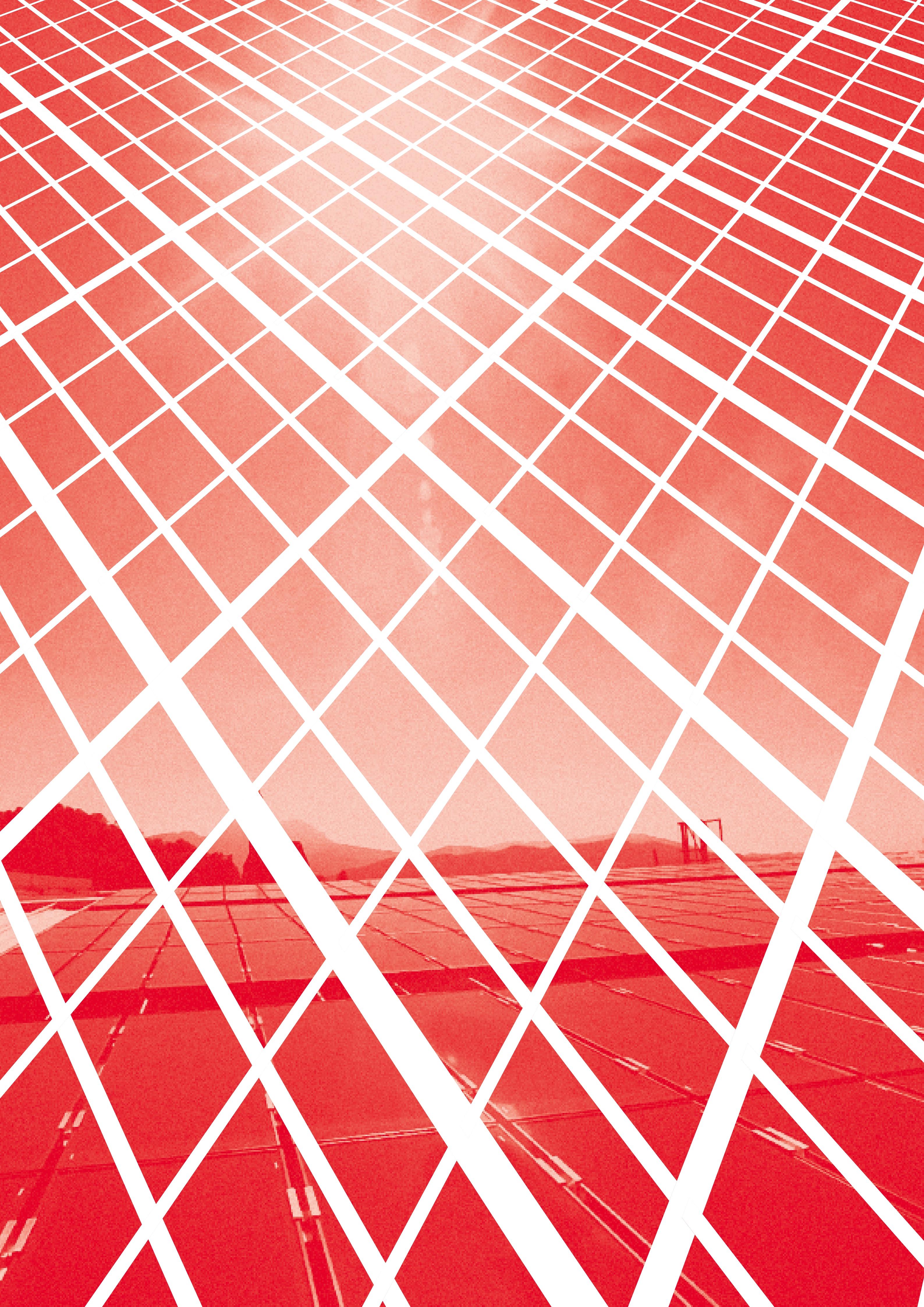
	2008	2009	2010	Total
Silicon	869	1,097	1,402	3,368
Wafers	604	708	1,104	2,416
Cells	345	404	631	1,380
Modules	345	404	631	1,380
Thin Film	606	1,011	788	2,406
Total	2,770	3,624	4,555	10,950

In order to meet the growth in demand projected in the scenarios, companies right along the PV value chain will need to upscale their production capacities. *Tables 3.5.* and *3.6.* give a breakdown of the investment needed in the PV industry up to 2010. The highest level of investment is required for silicon production and the upscaling of thin film production capacities. The *Advanced Scenario* projects a total investment of over 13 billion Euros in the period up to 2010.

In the light of the ongoing discussions about the level of government support for PV, however, it has to be pointed out that a considerable part of industry turnover will be reinvested in new production lines. Although in the long run this will have a positive impact on PV prices, due to economies of scale, in the short term reinvestment will inevitably limit the level of price reduction achievable.

Large PV power plant in Castejon, Spain

© Acciona Solar



Part Four:
Costs and Competitiveness

One of the main arguments heard from critics of solar electricity is that its costs are not yet competitive with those of conventional power sources. This is partly true. However, in assessing the competitiveness of photovoltaic power a number of considerations should be taken into account:

- **The type of PV application - grid-connected, off-grid or consumer goods.**
- **What exactly is PV competing with? What are the alternatives?**
- **The geographical location, initial investment costs and expected lifetime of the system.**
- **The real generation cost, bearing in mind that conventional sources are heavily subsidised and their 'external' costs from pollution and other effects are not accounted for.**
- **Progress being made in PV cost reduction.**

Competitiveness of consumer applications

PV consumer applications do not receive any subsidies and have been on the market for a long time. They have therefore already proved their competitiveness. Consumer applications not only provide improved convenience, but they also often replace environmentally hazardous batteries.

Large PV power plant


© Conergy

Competitiveness of off-grid applications

Off-grid applications are mostly already cost-competitive compared to the alternative options. PV is generally competing with diesel generators or the potential extension of the public electricity grid. The fuel costs for diesel generators are high, whilst solar energy's 'fuel' is both free and inexhaustible.

The high investment costs of installing renewable energy systems are often inappropriately compared to those of conventional energy technologies. In fact, particularly in remote locations, a combination of low operation and maintenance costs, absence of fuel expenses, increased reliability and longer operating lifetimes are all factors which offset initial investment costs. This kind of lifecycle accounting is not regularly used as a basis for comparison.

The other main alternative for rural electrification, the extension of the electricity grid, requires a considerable investment. Off-grid applications are therefore often the most suitable option to supply electricity in dispersed communities or those at great distances from the grid. However, although lifetime operating costs are much lower for off-grid PV than for other energy sources, initial investment costs can still be a barrier for people with little disposable income.

Competitiveness of grid-connected applications

Grid-connected applications, currently the biggest market segment, are expected to remain so for the foreseeable future. The generation costs of household PV systems, are in most cases, not yet competitive with residential electricity prices, unless there are support programmes. Electricity prices vary greatly, even within the 27 EU countries, with 2007 residential prices ranging, according to Eurostat, from between 7 and 26 €cents/kWh (including all taxes). The most recent trend has also been a steady increase. From 2005 to 2007, electricity prices in the 27 EU countries increased by an average of 16%. At the same time, PV generation costs have been decreasing, a trend expected to accelerate over the coming years.

Table 4.1: Expected PV generation costs for roof-top systems at different locations

	Sunshine hours	2007	2010	2020	2030
Berlin	900	0.44 €	0.35 €	0.20 €	0.13 €
Paris	1,000	0.39 €	0.31 €	0.18 €	0.12 €
Washington	1,200	0.33 €	0.26 €	0.15 €	0.10 €
Hong Kong	1,300	0.30 €	0.24 €	0.14 €	0.09 €
Sydney/Buenos Aires/ Bombay/Madrid	1,400	0.28 €	0.22 €	0.13 €	0.08 €
Bangkok	1,600	0.25 €	0.20 €	0.11 €	0.07 €
Los Angeles/Dubai	1,800	0.22 €	0.17 €	0.10 €	0.07 €

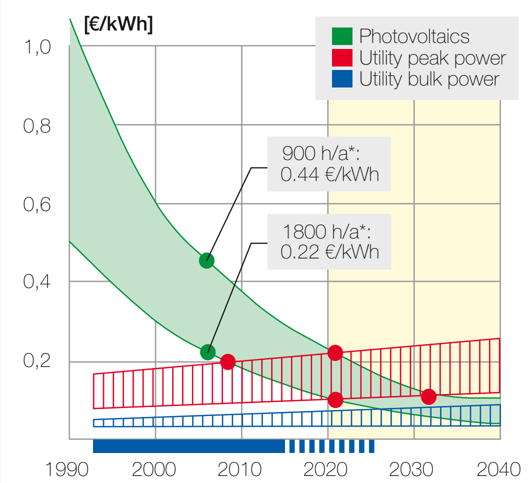
Note: The calculation method has been changed from the previous edition of 'Solar Generation'.

The simplest way to calculate the cost per kWh is to divide the price of the PV system by the number of kWh the system will generate over its lifetime. However, other variables such as financing costs may have to be taken into consideration. Figures for the cost per kWh of grid-connected systems frequently differ, depending on what assumptions are made for system costs, sunlight availability, system lifetime and the type of financing. *Table 4.1* includes financing costs (at a 5% interest rate) and a lifetime of 25 years, which is the same as the performance warranty period of many module producers. The figures are based on the expected system prices under the *Advanced Scenario*, where strong industrial growth is expected to drive down prices.

The figures in *Table 4.1*, giving PV generation costs for small distributed systems in some of the major cities of the world, show that by 2020 the cost of solar electricity will have more than halved. This would make it competitive with typical electricity prices paid by end consumer households. One reason is that whilst PV generation costs are consistently decreasing, general electricity prices are expected to increase. As soon as PV costs and residential electricity prices meet, 'grid parity' is achieved. With grid parity every kWh of PV power consumed will save money compared to the more expensive power from the grid. Grid parity is expected to be reached first in southern countries and then spread steadily towards the north.

Figure 4.1 shows the historical and expected future development of solar electricity costs. The falling curves show the reduction in costs in the geographical area between central Europe, for example Northern Germany (upper curve), and the very south of Europe (lower curve). In contrast to the falling costs for solar electricity the price for conventional electricity is expected to rise. The utility prices for electricity need to be divided into peak power prices (usually applicable around the middle of the day) and bulk power. In southern Europe solar electricity will become cost competitive with peak power within the next few years. Areas with less irradiation, such as central Europe, will follow suit in the period up to 2020.

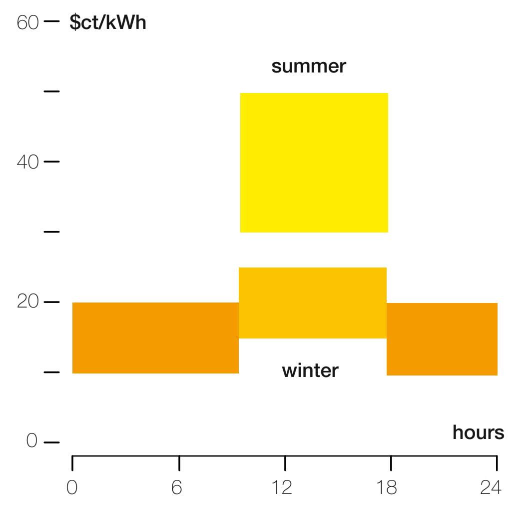
Figure 4.1: Development of utility prices and PV generation costs



*h/a: Hours of sun per annum
900 h/a corresponds to northern countries of Europe
1800 h/a corresponds to southern countries of Europe

Note: The blue band indicates that market support programmes will be necessary until about 2020 in some markets.

Figure 4.2: Range of household electricity prices in California



Source: Hyde, BSW-Solar 2006

Large scale PV systems are not in competition with residential electricity prices. In the long term, as the costs of PV components decrease, these systems will be able to compete with the generation costs of conventional fossil fuel or nuclear power plants. Large systems also have the advantage that bulk buying of PV modules and other system inputs lowers the price per kW considerably compared to roof top systems.

In some countries with a more liberalised power supply market, electricity prices are more responsive to demand peaks. In California or Japan, for example, electricity prices increase substantially during daytime, especially in the summer, as demand for electricity is highest during that period. Daytime, in particular in summer, is also the period when the electricity output of PV systems is at its highest. PV therefore serves the market at exactly the point when demand is greatest. During peak times, PV is already competitive in those markets. *Figure 3.2* illustrates the significant variation and high peak prices for household electricity in the Californian market.

It should also be pointed out here, that the prices for conventional electricity do not reflect the actual production costs. In many countries, conventional electricity sources such as nuclear power, coal or gas, have been heavily subsidised for many years. The financial support for renewable energy sources such as PV, offered until competitiveness is reached, should therefore be seen as a compensation for the subsidies that have been paid to conventional sources over the past decades.

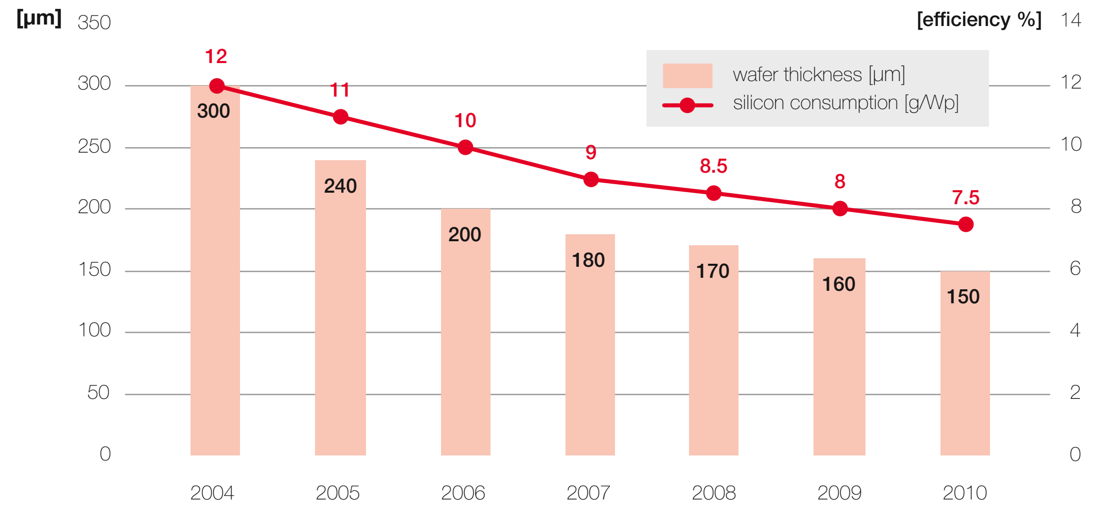
External costs of conventional electricity generation

The external costs to society incurred from burning fossil fuels or from nuclear generation are not included in most electricity prices. These costs have both a local and a global component, the latter mainly related to the consequences of climate change. There is uncertainly, however, about the magnitude of such costs, and they are difficult to identify. A respected European study, the 'Extern E' project, has assessed these costs for fossil fuels within a wide range, consisting of three levels:

- **Low: $4.3 per tonne of CO_2**
- **Medium $20.7 – 52.9/tonne CO_2**
- **High: $160/tonne CO_2**

PV pergola on the Forum in Barcelona

Figure 4.3: Development of silicon usage and wafer thickness



Taking a conservative approach, a value for the external costs of carbon dioxide emissions from fossil fuels could therefore be in the range of $10-20/tonne CO_2. As explained in the chapter 'Solar Benefits', PV reduces emissions of CO_2 by an average of 0.6 kg/kWh. The resulting average cost avoided for every kWh produced by solar energy, will therefore be in the range of 0.25-9.6 US cents/kWh.

The Stern Report on climate change, published by the UK government in 2006, concluded that any investment made now to reduce CO_2 emissions will be paid back easily in the future, through avoiding the external costs of fossil fuel consumption.

Factors affecting PV cost reductions

The cost of producing photovoltaic modules and other system inputs has fallen dramatically since the first PV systems entered the market. Some of the main factors responsible for that decrease have been:

- **Technological innovations and improvements**
- **Increasing the performance ratio of PV**
- **Extension of PV systems' lifetime**
- **Economies of scale**

These factors will also drive further reductions in productions costs. It is clearly an essential goal for the solar industry to ensure that prices fall dramatically over the coming years. Against this background, EPIA has laid down specific targets for technological improvements:

Targets for crystalline cells

Crystalline Cz efficiency to reach 20% by 2010 and 22% by 2020

Crystalline Mz efficiency to reach 18% by 2010 and 20% by 2020

Ribbon-sheet efficiency to reach 17% by 2010 and 19% by 2020

Targets for thin film technology

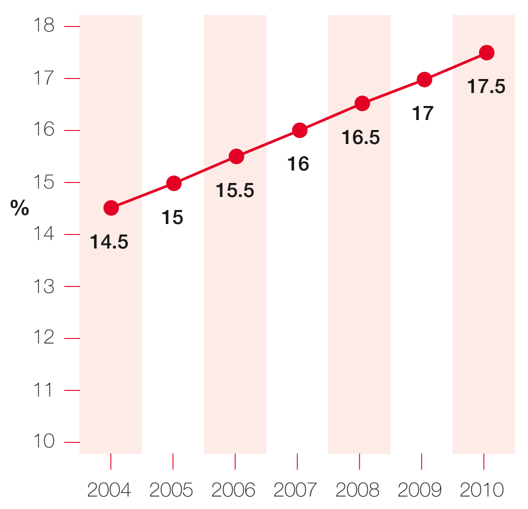
Thin film efficiencies to reach between 10% and 12% (for a-Si/mc-Si, CIS and CdTe) by 2010 and then 15% by 2020

Building Integrated PV costs to fall between 2005 and 2010 by 50% and by a further 50% by 2020

Typical industrial PV processing area to increase from a size of 1 to 3 m^2 by 2010 and to 9 m^2 by 2020

By increasing the efficiency of PV modules, both thin film and crystalline, production costs per kWh will fall. At the same time, less and less raw material will be used, especially for crystalline technologies. The ability to produce thinner wafers will reduce silicon consumption and therefore costs, as well as the energy payback time of PV systems.

Figure 4.4: Development of average cell efficiency for crystalline cells



However, the improvement of existing technologies is not the only factor that will drive down production costs. R&D expenditures on PV are growing and delivering promising results for new technologies, based on innovative production processes or different raw materials. A good example of significant production cost reduction has been through the development of thin film technologies. Similar breakthroughs can be expected from future technologies such as organic cells or nanotechnologies.

PV plant in Pellworm

© Schott Solar

PV system quality is also a parameter which influences the cost per kWh. The quality of the system is reflected in its **performance ratio**. This is the ratio of the electricity measured on the AC side of the electricity meter, compared to the amount of electricity originally generated by the PV modules. The higher the performance ratio, the lower the losses between the modules and the point at which the system feeds into the grid. The expected range of system performance ratios is between 70% and 85%, but in recent years the trend has been towards the upper part of this range. This means that if losses and malfunctioning of PV systems can be reduced further, the cost per kWh can also be lowered.

A further **extension of system lifetime** will have a positive effect on the generation costs of PV/kWh, as the electricity output will increase. Many producers already give module performance warranties for 25 years. Twenty-five years can therefore be considered as a minimum module lifetime. An extension of their lifetime to 35 years by 2010, was forecast in the 2004 'EPIA Roadmap' study.

Another very important driver for PV cost reduction is **economies of scale**. Larger production volumes enable the industry to lower the cost per produced unit. Economies of scale can be realised during the purchasing of raw materials through bulk buying, and during the production processes by obtaining more favourable interest rates for financing and by efficient marketing. Whilst only a decade ago cell and module production plants had capacities of just a few MW, today's market leaders have 1 GW capacity plants within their reach. This capacity increase is expected to decrease costs per unit by approximately 20% for each time production output is doubled.

Winners and losers

The rapid rise in the price of crude oil in recent years, and the subsequent knock-on effect on conventional energy costs across the global domestic and industrial sectors, has once again highlighted the urgent need for both industrialised and less developed economies to rebalance their energy mix. This increase in oil price is not just the result of concerns about security of supply. It also reflects the rapidly rising demand for energy in the emerging economies of Asia, particularly China. Oil production can no longer expand fast enough to keep up with demand. As a result, higher oil prices – and consequently higher energy prices in general - are here to stay and world economies will have to adjust to meet this challenge.

It is against this background of runaway energy prices that those economies which have committed themselves to promoting the uptake of solar electricity, are starting to differentiate themselves from those countries that have relied heavily or almost exclusively on conventional energy sources. There are clear signs that the next decade will see many countries having to rapidly reduce their dependence on imported oil and gas. This abrupt transition will be felt hardest by those that have paid little attention so far to the role that solar electricity can play. However, on the positive side, there is still time for them to catch up if they introduce innovative policies quickly to promote solar electricity use.

The speed with which the solar electricity sector is increasing its market share in those economies that have committed themselves to promote this clean power source, coupled with the transformation of its customers from power recipients to power generators, represents a revolution comparable to that in the telecommunications market over the past decade. Such industrial revolutions produce winners and losers.

The undisputed winners in such industrial revolutions are the customers who have access to greater choice. Other winners include the market players who recognise the potential of such an expanding market, and those who have committed themselves to investment in the sector. However, there are also many examples of innovative products and services where offering customer choice has led to their popular uptake at a price considerably higher than that previously available.

Two examples of such innovative market entrants are mobile phones, offering a service at a far higher price than conventional fixed-line networks, and bottled mineral water, a product which in the middle and higher price ranges costs more per litre than petrol. With the right product - offering customers the type of added value they are looking for, coupled with innovative marketing - technologies such as solar electricity should be able to compete with conventional grid supplied power in industrialised countries.

The extension of customer choice in the electricity sector to embrace solar power, however, requires a commitment to creating an appropriate framework to allow consumers to access solar power in an efficient and cost-effective way.

Cell production line at Q-Cells

Part Five:
Solar Benefits

Photovoltaic power systems offer many unique benefits above and beyond simple energy delivery. That is why comparisons with conventional electricity generation - and more particularly comparison with the unit energy costs of conventional generation - are not always valid. If the amenity value of the energy service that PV provides, or other non-energy benefits, could be appropriately priced, the overall economics of PV generation would be dramatically improved in numerous applications, even in some grid-connected situations. PV also offers important social benefits in terms of job creation, energy independence and rural development.

Space-saving installations

PV is a simple, low-risk technology that can be installed virtually anywhere where there is available light. This means that there is a huge potential for the use of roofs or façades on public, private and industrial buildings. PV modules can be used as part of a building's envelope, providing protection from wind and rain or serving to shade the interior. During their operation, such systems can also help reduce buildings' heating loads or assist in ventilation through convection.

UEA in Norwich

© BP Solar

Other places where PV can be installed include the sound barriers along communication links such as motorways. In satisfying a significant part of the electricity needs of the industrialised world, there will be no need to exploit otherwise undisturbed areas.

Improving the electricity network

For power companies and their customers, PV has the advantage of providing relatively quick and modular deployment. PV can help to strengthen the electricity network, particularly at the end of the distribution line. Since power is generated close to the point of use, such distributed generators can reduce transmission losses, improve service reliability for customers and help limit maximum demand.

Employment

PV offers important social benefits in terms of job creation. Significantly, much of the employment creation is at the point of installation (installers, retailers and service engineers), giving a boost to local economies. Based on information provided by the industry, it has been assumed that 10 jobs are created per MW during production and about 33 jobs per MW during the process of installation. Wholesaling of the systems and indirect supply (for example in the production process) each create 3-4 jobs per MW. Research adds another 1-2 jobs per MW. Over the coming decades, it can be assumed that these numbers will decrease as the use of automated machines will increase. This will be especially the case for jobs involved in the production process.

Table 5.1: Worldwide employment in PV-related jobs under *Solar Generation Scenarios*

year	Installation	Production	Wholesaler	Research	Supply	Total
Advanced Scenario						
2007	77,688	22,968	6,890	2,986	8,613	119,145
2010	220,162	62,546	18,764	8,131	23,455	333,058
2015	559,282	147,373	44,212	19,159	55,265	825,292
2020	1,632,586	393,530	118,059	51,159	147,574	2,342,907
2025	3,877,742	839,338	251,801	109,114	314,752	5,392,747
2030	7,428,118	1,406,841	422,052	182,889	527,565	9,967,466
Moderate Scenario						
2007	77,688	22,968	6,890	2,986	8,613	119,145
2010	166,518	47,306	14,192	6,150	17,740	251,906
2015	486,219	128,121	38,436	16,656	48,045	717,478
2020	1,018,552	245,519	73,656	31,917	92,070	1,461,713
2025	1,806,321	390,978	117,294	50,827	146,617	2,512,037
2030	2,770,569	524,729	157,419	68,215	196,773	3,717,705

*For 2006 EPIA data is used. For later years the figures are based on extrapolation of IEA data.

In 2007, the German PV industry alone employed 42,000 people. Such an impact on the national job market would be impressive for any source of energy. In Germany, there are in fact currently more jobs in the PV sector than in the nuclear industry.

By 2030, following the Solar Generation *Advanced Scenario*, it is estimated that 10 million full-time jobs would have been created by the development of solar power around the world. Over half of those would be in the installation and marketing of systems.

Maison du tourisme à Alès, France

The Alliance for Rural Electrification (ARE) is an international non-profit organisation founded in 2006 by the main European and international renewable energy industry associations:

European Photovoltaic Industry Association (EPIA), *European Small Hydropower Association* (ESHA), *European Wind Energy Association* (EWEA), *European Biomass Industry Association* (EUBIA) and the *Global Wind Energy Council* (GWEC).

ARE was created in response to the need for access to sustainable electricity in the developing world, and to facilitate the involvement of its members in emerging rural energy markets. The strength of ARE lies in its robust industry-based approach, coupled with the ability to combine different renewable energy sources so as to provide more efficient and reliable solutions for rural electrification. ARE´s **activities** include: facilitating updated information for its members about project funding programmes, partner matching or new financing instruments; establishing the necessary **links and partnerships** with EU institutions, international organisations and financial institutions to **create, promote and reinforce** favourable policies and markets towards the use of renewable energies within rural areas, and **developing the appropriate communication** tools and materials to disseminate its messages. ARE also supports the **implementation of projects based on socially and environmentally responsible actions** towards the electrification of rural areas with renewable energies.

Rural electrification

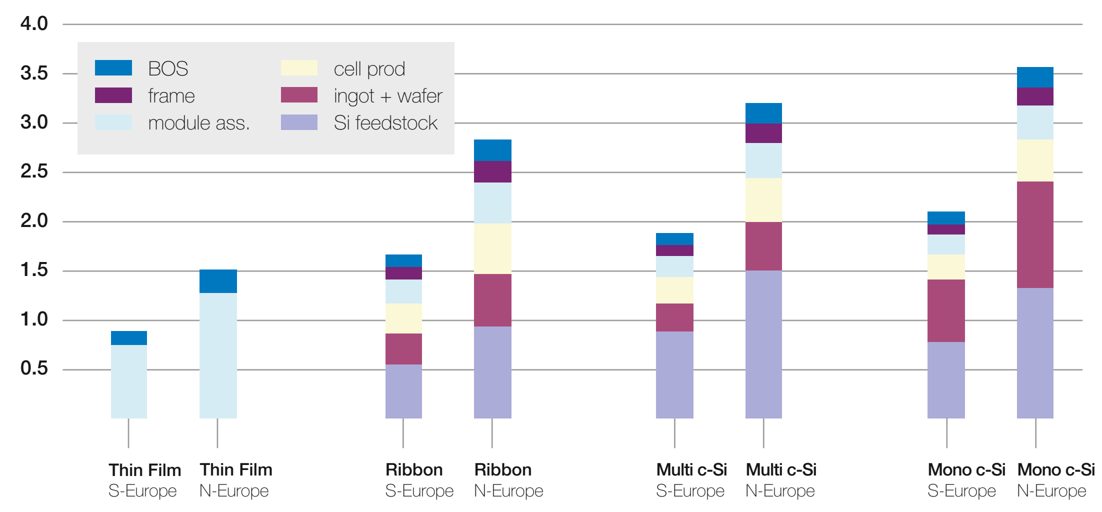
Solar power can be easily installed in remote and rural areas, places that may not be targeted for grid connection for many years. Renewable energy sources such as PV are currently one of the few suitable options to supply electricity in areas of dispersed communities or those at a large distance from the grid. Decentralised (off-grid) rural electrification based on the installation of stand-alone systems in rural households or the setting up of minigrids - where PV can be combined with other renewable energy technologies or with LPG/diesel - enables the provision of key services such as lighting, refrigeration, education, communication and health. This increases economic productivity, and creates new income generation opportunities. Furthermore, the technologies which are used to power off-grid applications (stand-alone PV systems, PV water pumping systems and hybrids) are often both affordable and environmentally sound. Due to their robustness, ease of installation and flexibility, PV systems are able to adapt to almost any rural energy demand in any part of the world.

PV system in a school in Cambodia

The load demand expected from small PV systems is usually focused on serving household (lighting, TV/ radio, small home appliances) and social needs (health and community centres, schools, water extraction and supply), bringing both quality of life and economic improvements. For larger and hybrid systems, the power supply can be extended to cover working hours and productive loads. This could range from minor applications such as air ventilators, refrigerators and hand machine tools through to larger demands such us the electrification of schools, hospitals, shops and farms.

During 2007, around 100 MW of PV solar energy was installed in rural areas in developing countries, enabling access to electricity for approximately 1,000,000 families.

Figure 5.1: Energy payback times for range of PV systems
(rooftop system, irrad. 1700 resp. 1000 kWh/m²/year)



Source: Alsema, De Wild, Fthenakis, 21st European Photovoltaic Energy Conference

Energy payback

A popular belief still persists that PV systems cannot ‘pay back’ their energy investment within the expected lifetime of a solar generator – about 25 years. This is because the energy expended, especially during the production of solar cells, is seen to outweigh the energy eventually generated.

Data from recent studies shows, however, that present-day systems already have an energy payback time (EPBT) – the time taken for power generation to compensate for the energy used in production – of 1 to 3.5 years, well below their expected lifetime. With increased cell efficiency and a decrease in cell thickness, as well as optimised production procedures, it is anticipated that the EPBT for grid-connected PV will decrease further.

Figure 5.1 shows energy payback times for different solar cell technologies (thin film, ribbon, multicrystalline and monocrystalline) at different locations (southern and northern Europe). The energy input into a PV system is made up of a number of elements, including the frame, module assembly, cell production, ingot and wafer production and the silicon feedstock. The energy payback time for thin film systems is already less than a year in southern Europe. PV systems with monocrystalline modules in northern Europe, on the other hand, will pay back their input energy within 3.5 years.

La Dentellière – Social Home

Climate protection

The most important feature of solar PV systems is that there are no emissions of carbon dioxide - the main gas responsible for global climate change - during their operation. Although indirect emissions of CO_2 occur at other stages of the lifecycle, these are significantly lower than the avoided emissions.

PV does not involve any other polluting emissions or the type of environmental safety concerns associated with conventional generation technologies. There is no pollution in the form of exhaust fumes or noise. Decommissioning a system is unproblematic.

Although there are no CO_2 emissions during operation, a small amount does result from the production stage. PV only emits 21–65 grams CO_2/kWh, however, depending on the PV technology. The average emissions for thermal power in Europe, on the other hand, are 900g CO_2/kWh. By substituting PV for thermal power, a saving of 835–879 g/kWh is achieved.

The benefit to be obtained from carbon dioxide reductions in a country's energy mix is dependent on which other generation method, or energy use, solar power is replacing. Where off-grid systems replace diesel generators, they will achieve CO_2 savings of about 1 kg per kilowatt-hour. Due to their tremendous inefficiency, the replacement of a kerosene lamp will lead to even larger savings, of up to 350 kg per year from a single 40 Wp module, equal to 25kg CO_2/kWh. For consumer applications and remote industrial markets, on the other hand, it is very difficult to identify exact CO_2 savings per kilowatt-hour. Over the whole scenario period, it was therefore estimated that an average of 600 g CO_2 would be saved per kilowatt-hour of output from a solar generator. This approach is rather conservative; higher CO_2 savings may well be possible.

Building HLM in Echirolles, France


© Tenesol

Recycling of PV modules is possible and raw materials can be reused. As a result, the energy input associated with PV will be further reduced.

If governments adopt a wider use of PV in their national energy generation, solar power can therefore make a substantial contribution towards international commitments to reduce emissions of greenhouse gases and their contribution to climate change.

By 2030, according to the *Solar Generation Advanced Scenario*, solar PV would have reduced annual global CO_2 emissions by just over 1,6 billion tonnes. This reduction is equivalent to the output from 450 coal-fired power plants (average size 750 MW). Cumulative CO_2 savings from solar electricity generation between 2005 and 2030 will have reached a level of 9 billion tonnes.

Carbon dioxide is responsible for more than 50% of the man-made greenhouse effect, making it the most important contributor to climate change. It is produced mainly by the burning of fossil fuels. Natural gas is the most environmentally sound of the fossil fuels, because it produces roughly half as much carbon dioxide as coal, and less of other polluting gases. Nuclear power produces very little CO_2, but has other major safety, security, proliferation and pollution problems associated with its operation and waste products. The consequences of climate change are already apparent today (see panel *'Scientific Assessment of Climate Change'*).

Table 5.2: CO_2 savings under the *Solar Generation Scenarios*

	Advanced Scenario		Moderate Scenario	
	CO_2 savings annually in Mt	**CO_2 savings accumulated in Mt**	**CO_2 savings annually in Mt**	**CO_2 savings accumulated in Mt**
2006	5	20	5	20
2007	6	27	6	27
2008	9	36	8	35
2009	12	48	11	46
2010	17	65	15	61
2011	23	89	19	80
2012	29	118	27	107
2013	37	155	35	142
2014	48	203	45	188
2015	62	265	58	245
2016	80	344	72	317
2017	107	451	94	412
2018	136	588	116	528
2019	171	759	141	669
2020	217	976	170	839
2021	273	1,249	203	1,042
2022	341	1,590	242	1,284
2023	422	2,012	286	1,570
2024	521	2,533	336	1,906
2025	639	3,172	391	2,297
2026	783	3,955	456	2,752
2027	943	4,897	524	3,276
2028	1,127	6,025	599	3,876
2029	1,341	7,365	682	4,558
2030	1,588	8,953	775	5,333

Cell production at Q-Cells

Scientific Assessment of Climate Change

In February 2007, the Intergovernmental Panel on Climate Change (IPCC) released the first of a series of reports which make up its Fourth Assessment Report. 'Climate Change 2007: The Physical Science Basis' assesses the current scientific knowledge of the natural and human drivers behind climate change. It also assesses observed changes in climate, the ability of science to attribute changes to different causes, and projections for future climate change. This report expresses much greater confidence than past assessments that most of the observed warming over the past half-century is caused by human activities (greater than 90% certainty). It concludes (from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea levels), that warming of the climate system is unequivocal.

Among the observed impacts detailed in the report are:

- Eleven of the last twelve years rank among the twelve hottest on record.
- Global sea level rise has accelerated.
- Mountain glaciers and snow cover have declined on average in both the northern and southern hemispheres.
- More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics.

Projected climate change by the end of the 21st century depends on the level of future emissions, and the IPCC used six defined emission scenarios for its projections. The report concludes that if we take no action to reduce emissions, there will be twice as much warming over the next two decades than if we had stabilised heat-trapping gases at 2000 levels.

Among the projections included in the report are:

- The range of projected temperature increase over the present century is 1.1 to 6.4 °C.
- The best estimate range, which reflects the centre point of the lowest and highest emission scenarios, is for a 1.8 to 4 °C increase.
- It is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with higher peak wind speeds and more heavy precipitation associated with warmer tropical seas.
- There is a greater than 90% likelihood that extreme heat, longer heat waves and heavy precipitation events will continue to become more frequent.

Some of the report's key findings are:

- It is likely that climate change will induce mass extinction of species within 60-70 years. We have already seen the climate-linked extinction of some frog species, but this is just the tip of the iceberg. The scale of risk is larger than most of the five major extinction events that have occurred in the earth's history.
- Over the next decades, the number of people at risk of water scarcity is likely to rise from tens of millions to billions. Steadily decreasing water availability is projected for India and other parts of South Asia and Africa. Whilst the poorest parts of the world are going to the hardest hit, wealthy countries such as Australia and nations in Southern Europe are also in the front line.
- Reductions in food production capacity in the poorest parts of the world are projected, bringing more hunger and misery and undermining achievement of the millennium development goals. Within a few decades, it is likely that we will see climate change-induced wheat, maize and rice production falls in India and China.
- Increased drought and water scarcity are likely to lead to growing problems of hunger and human dislocation in Africa over the coming decades.
- The loss of glaciers in Asia, Latin America and Europe are set to cause major water supply problems for a large fraction of the world's population, as well as a massive increase in glacial lake outburst floods and other risks for those living in the glaciated mountains.
- Huge numbers of people will be at risk due to sea level rise, storm surge and river flooding in the Asian megadeltas such as the Ganges-Brahmaputra (Bangladesh) and the Zhujiang (China).
- Warming of more than another degree could commit the world to multi-metre sea level rise over several centuries, from the partial or total loss of the Greenland and West Antarctic ice sheets. Huge coastal dislocation would result.

The Kyoto Protocol

The Kyoto Protocol specifies legally-binding targets and timetables for reductions of greenhouse gases by the developed countries, amounting to a nominal 5% reduction of emissions by 2008-2012 relative to 1990 levels. The Protocol was initially signed by 84 countries, and 166 have since ratified or acceded to it. The Protocol requires that at least 55 countries, accounting for 55% of the CO_2 emissions from Annex B (industrialised) countries, ratify in order for it to enter into force. Having passed the numbers test in 2002, the Kyoto Protocol finally passed the second hurdle when the Russian Federation deposited its instrument of ratification with the United Nations in November 2004. The Protocol entered into force and became legally binding on 16 February, 2005.

The United States government has withdrawn from the Kyoto process and shows no sign of re-entering, for at least as long as the Bush administration is in power. The only remaining Annex B country – besides the USA – ratified the Kyoto Protocol in December 2007: Australia.

The Kyoto signatories must now get serious about meeting their targets, both through domestic emissions reduction measures and through the use of the various trading mechanisms outlined in the Protocol. Formal preparations are underway for creating a 'global' carbon market for emissions trading from 2008, and the European Emissions Trading System (ETS) is already up and running.

The so-called 'flexible mechanisms', the Clean Development Mechanism (CDM) and Joint Implementation (JI) are also operational, and projects are being developed and approved at an ever-increasing rate.

The Clean Development Mechanism allows industrialised countries to invest in projects in developing countries which contribute to the reduction of greenhouse gas emissions in that country. An example would be Canada financing an energy efficiency project in China, or Japan financing a renewable energy project in Morocco. These projects must have the approval of the CDM Executive Board, and must also generate measurable emissions reductions against a business-as-usual baseline. They must satisfy 'additionality' - it must be clear that the projects would not have happened anyway. They should also be designed to contribute to sustainable development in the partner developing countries.

Joint Implementation allows industrialised countries with emissions reductions targets to cooperate in meeting them. For example, German-financed energy efficiency projects in Russia, or Norwegian-financed renewable energy projects in Hungary, which generate emissions reductions, can be credited to the country which finances them. In theory, this is a more economically efficient way for industrialised countries to generate the same overall emissions reductions.

Security of supply

The EPIA/Greenpeace *Advanced Scenario* shows that by 2030, PV systems could be generating approximately 2,600 TWh of electricity around the world. This means that enough solar power would be produced globally to supply more than half of the current EU electricity needs, or replace 450 coal-fired power plants (average size 750 MW).

Global installed capacity of solar power systems could reach 1,800 GW by 2030. About 73% of this would be in the grid-connected market, mainly in industrialised countries. Assuming that their average consumption per 2.5 person household is 3,800 kWh, the total number of people by then generating their electricity from a grid-connected solar system would reach 1.280 billion.

Although the key markets are currently located mainly in the industrialised world, a global shift will result in a significant share being taken by the now developing world in 2030. Since system sizes are much smaller than grid-connected systems, and the population density greater, this means that up to 3.2 billion people in developing countries would by then be using solar electricity. This would represent a considerable breakthrough for the technology from its present emerging status.

Part Six:
Policy Drivers

The feed-in tariff: driver of Europe's solar success story

It is evident that without the support of suitable instruments, the expansion of the worldwide solar electricity market will not happen at sufficient speed. In order to accelerate the reconstruction of our electricity supply system, it is necessary to implement powerful and efficient tools supporting the use of solar electricity. Over a number of years, the premium feed-in tariff has proved its power and efficiency in developing new markets.

Worldwide, people are surprised by the fact that Germany, a country which is not one of the sunniest places in the world, has developed the most dynamic solar electricity market and a flourishing PV industry. How could this happen? Many different types of programmes have been tried in many countries in the past, in order to accelerate the PV market, but none has been as successful in such a short period of time as the feed-in tariff in Germany. The idea has been adapted for use in other European states, with each country adjusting the system according to its specific needs. Extending such feed-in tariff mechanisms beyond Germany is a cornerstone of the European Photovoltaic Industry Association's strategy for promoting the uptake of solar electricity in Europe. The simplicity of the concept, and its low administrative costs, mean that it is a highly effective tool for boosting the contribution of solar electricity in national energy mixes.

The basic idea behind a feed-in tariff is very simple. Producers of solar electricity

- **have the right to feed solar electricity into the public grid**
- **receive a premium tariff per generated kWh reflecting the benefits of solar electricity compared to electricity generated from fossil fuels or nuclear power**
- **receive the premium tariff over a fixed period of time**

All three aspects are simple, but it took significant effort to establish them. For many years, the power utilities did not allow the input of solar electricity into their grid and this is still the case in many countries even today. Therefore, that right cannot be taken for granted, and will need to be argued for, when facing the likely continued opposition of utilities.

Feed-in tariff: A temporary measure to develop the market

As the chapter on costs has already explained, feed-in tariffs are a temporary measure to develop the competitiveness that will result from economies of scale. Competitiveness with conventional electricity sources will be reached in different regions at different times. Feed-in tariff systems therefore need to be adapted to national conditions. However, it is important that tariffs are paid over a period of roughly 20 years from the day the system is connected to the grid, because the costs will be related to the initial investment. In some years' time, investment costs will be low enough that they can be paid off without using the support of premium feed-in tariffs.

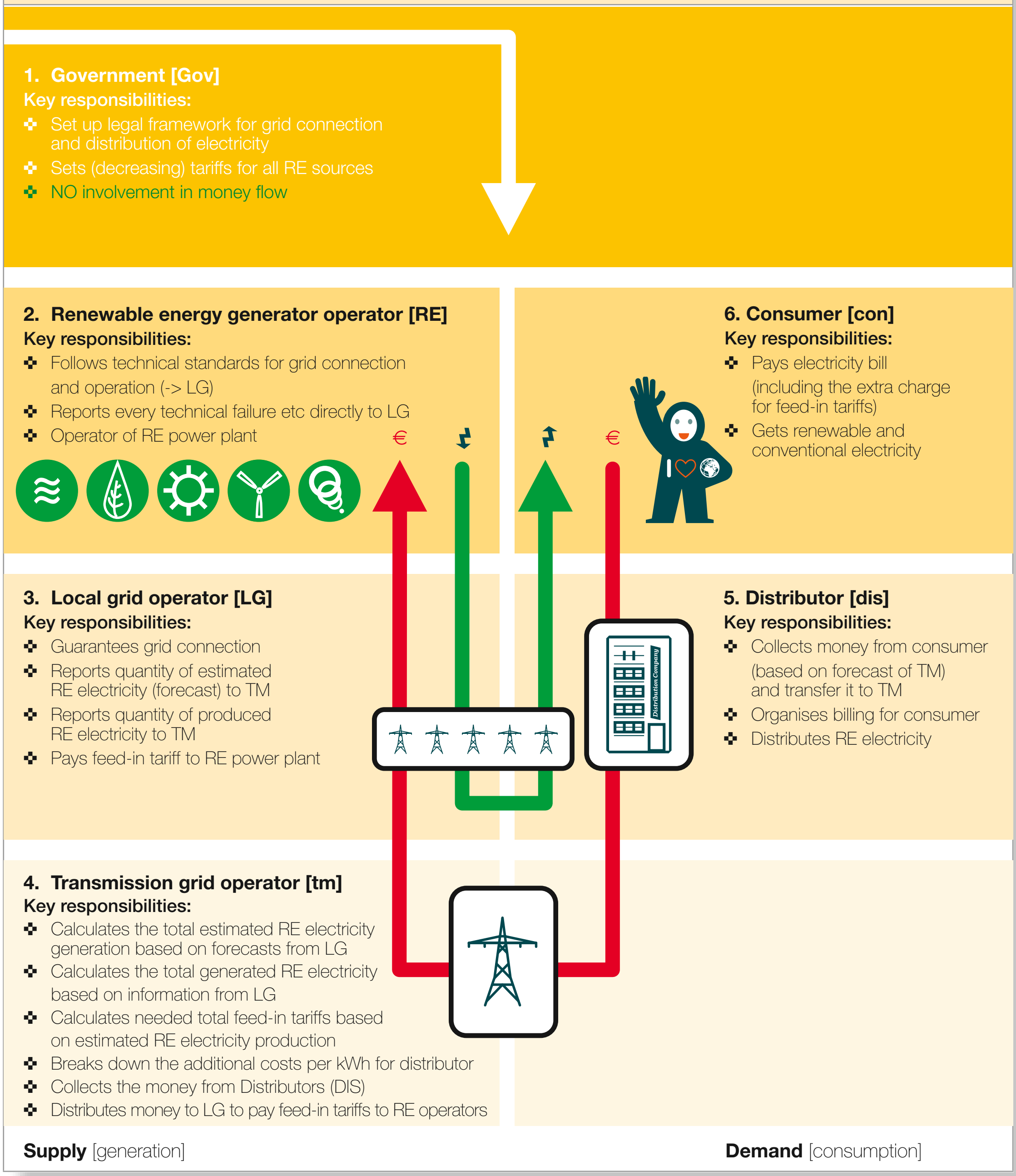
Feed-in tariff: Who pays for it?

In the past, in order to encourage solar electricity, many programmes were financed through government budgets. The disadvantage of this method has been that if the state money ran out, or was curtailed, the programme could be stopped. Therefore, some feed-in tariff models take a completely different approach. In Germany in 2008, the utilities pay a tariff of between €0.35/kWh and €0.47/kWh (depending on the size and type of system) for solar electricity from newly-installed PV arrays. The utilities are authorised to pass on this extra cost, spread equally, to all electricity consumers through their regular electricity bill. This means that the feed-in programme works independently from the state economy, and the extra cost which each electricity consumer has to pay, in order to increase the share of renewable energy in the national electricity portfolio, is very small. In Germany, the monthly extra costs per household due to the tariff for solar electricity are currently €1.25. The result is also that every electricity consumer contributes to the restructuring of the national electricity supply network, away from a fossil-based one, and towards a sustainable and independent structure.

Feed-in tariff: The driver of cost reduction

The costs for solar electricity have been reduced consistently since the technology was first introduced to the market. Even so, in most cases solar electricity cannot yet compete with grid electricity generated from fossil fuels. Whilst it is expected that prices for electricity generated from fossil fuels will keep rising, it

Renewable Energy Law (EEG) in Germany – how does it work in practice?



is still very important to maintain a strong momentum in bringing down the costs for solar electricity.

For this reason, the feed-in tariff in Germany is reduced each year by 5% (from 2009 the degression rate will be increased to 8 -10 %), but only for newly-installed PV systems. Once a PV system is connected to the grid, the tariff remains constant over the complete period of 20 years. Through this 5% annual reduction, there is therefore constant pressure on the PV industry to bring the costs for solar electricity down by 5% each year in order to keep the market alive. At the same time, the customer can easily calculate the return on investment in their PV system. This planning security is an essential element of the success story of the feed-in tariff.

Feed-in tariff: The driver of high-quality solar electricity systems

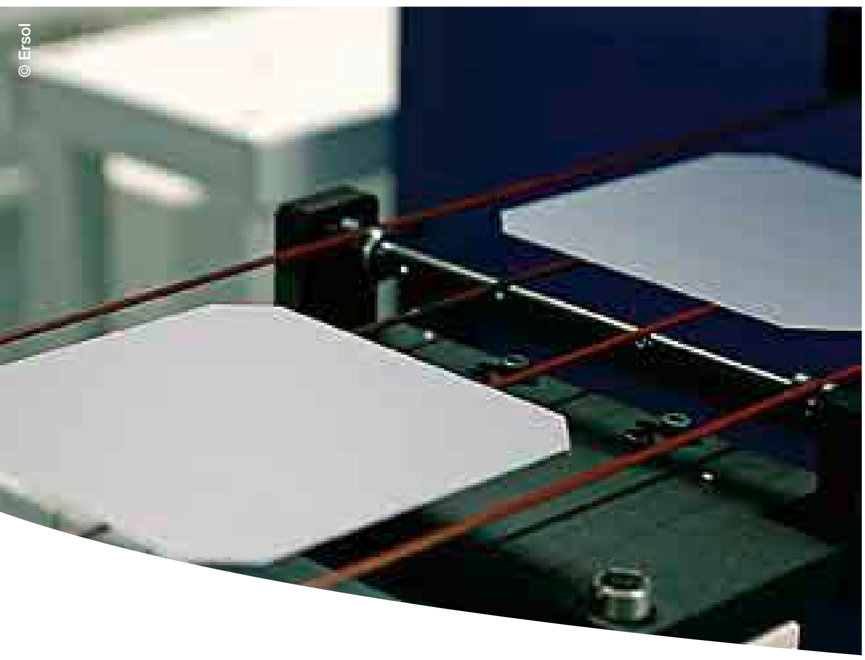
Many solar electricity support programmes are based on an investment subsidy in order to reduce the barrier of high up-front capital costs. The drawback of such an approach, is the missing incentive to invest in high-quality solar electricity systems and to ensure their efficient operation and maintenance. If the customer receives a fixed payment per installed capacity unit, there is no incentive to go for high-quality products, which usually means a higher price, or to operate the system at the highest possible level. With the feed-in tariff, the return on investment is heavily dependent on the performance of the PV system. The customer gets his return on investment with each kWh that is fed into the grid. Therefore, maximising the power output of the PV system over its whole lifetime is essential to the customer, ensuring that the PV system will be well operated and maintained.

The feed-in tariff is the only system that rewards the generation of solar electricity appropriately and not simply for installing a system.

Feed-in tariff: The driver of easier financing

The up-front costs for solar electricity systems are a clear barrier to wider market penetration. As already explained, investment subsidies have been implemented in many countries in order to overcome this barrier, but this approach has significant disadvantages. A feed-in tariff guaranteed by law over a sufficient period of time, serves as an excellent security for the customer's bank in order to finance the system. The PV system itself, combined with the guaranteed feed-in tariff over 20 years in Germany, is usually sufficient to receive a loan from the bank. Of course, it took some time until banks became familiar with PV systems and the implications of the feed-in tariff, but nowadays the financing of PV systems via a bank loan in Germany is no longer an unusual and time-consuming activity, but very common and straightforward.

PV Cell production process - Ersol



Feed-In Tariff – Core Elements

- An efficient tool that has already proved to be successful
- A temporary mechanism
- Not a burden on taxpayers
- The driver for further cost reductions and economies of scale
- Ensures high-quality PV systems and good performance
- Creates secure conditions for potential investors

Important co-measures:

- The removal of administrative barriers
- Guaranteed grid access

The feed-in tariff needs strong co-drivers

Simple and quick administration

There are countries in Europe with an economically attractive feed-in tariff in place but without a viable PV market. How can this happen? The feed-in tariff needs a strong partner in order to release its full power; this is a simple and quick approval process. Even if an excellent feed-in tariff is in place, but the procedures for the approval of PV installations and their connection to the grid take many months, perhaps even more than a year, the number of potential customers will remain limited. The customer's effort in dealing with administrative and licensing issues therefore needs to be kept to a minimum. A complex and time-consuming administration and licensing process, is a clear indication that an electricity market has not yet made substantial progress towards liberalisation.

Guaranteed grid access

Given its major social and environmental advantages, solar electricity should be given priority and guaranteed access to the grid. In many countries, there is an enormous over-capacity in conventional electricity generation, with a range of power sources – from fossil fuels through to renewables – all jostling for the right to be fed into the grid. Solar electricity generators must be guaranteed automatic access, because of their high ecological and technical value, including support for local grid stability.

Government and industry commitment

Governments that have taken steps to broaden their energy supply base with an abundant clean technology, such as photovoltaics, will also be able to count themselves among the winners. Such diversification not only brings benefits in terms of greater security of energy supply, but also leads to wider environmental benefits though the deployment of zero-emission technologies that, according to the predictions presented here, will make a significant impact on global CO_2 emissions over the coming decades.

At present, the nations of the industrialised world vary greatly in their commitment to solar electricity. While countries such as Germany and Japan, as well as others in Europe, have moved forward from discussion to implementing the necessary support schemes, others have actually cut back their solar electricity programmes.

Both industry and governments, however, will have to expand their respective commitments to the solar sector if the potential identified in this report is to be fully exploited. On the industry side, continuing and accelerated investment in the expansion of production facilities is needed in order to meet the demands of the market and to ensure that the cost, and ultimately the price, of the technology is brought down through production up-scaling and introduction of new manufacturing techniques and materials. On the government side, commitment to the solar electricity sector in many countries needs to be extended through such actions as the introduction of premium tariffs, and the adaptation of building regulations to provide a greater incentive for the deployment of solar electricity systems in the built environment.

Like every other industry, the solar electricity sector will only move forward if sufficient investment is committed to provide for its expansion. Over the past few years, the solar industry has been very successful in drawing the attention of the financial world to this young and dynamic market. A 'solar boom' is still evident in the investment community. Both industry and governments need to ensure that the financial world maintains interest in renewables, in order to make sure that the necessary financing is in place to keep up the current rate of expansion.

In summary, there is no doubt that the global electricity business will undergo a significant expansion over the next few decades. All indicators point in that direction. Solar power will certainly play an ever more significant role in the supply mix. However, the extent to which solar electricity will make its impact on that market will depend very much on ensuring that the potential winners in this business are made fully aware of the opportunities available.

Those opportunities will only be realised if both industry and governments continue to strengthen their commitment to broadening the energy supply base and, through the deployment of solar electricity technologies, offer greater choice to customers. This will have the added benefit of demystifying the energy process and giving individuals greater control over the provision of their electricity needs. This in itself constitutes a revolution in the energy market.

Building with integrated PV systems

International policy on PV solar power

Germany

Market situation in 2007

The cumulative installed power of PV systems in Germany increased to 3,8 GW by the end of 2007. Annually installed power in 2007 was approximately 1100 MW. Germany remained the most important global PV market. About half of the global installations took place in Germany. Although the absolute market figures keep growing in Germany, the market share of Germany in Europe was shrinkingEurope during the last year as markets like Spain and Italy finally followed the successful German path. Germany has a diverse mix of PV applications. In 2007 30% of the German PV systems were installed on residential homes (1-10 kW). 53% were installed on farm houses, multi-family houses, public and social buildings or were commercial plants in the range between 10-100 kW. 7% were very large commercial roof top systems (>100 kW) and 10 % of the PV systems were installed as very large ground mounted systems. 0.6% of electricity consumption can already be provided by PV. Considering current installation rates PV will be a major electricity source in Germany within a few years.

Short term market outlook

The industry believes that until 2012 the annual market could grow to 2,400 MW under favorable conditions. The EEG (German Feed-In Law) must

Adjustment in feed in tariff digression rate in Germany

	2008	2009	2010	2011
Roof top <100 kWp	5%	8%	8%	9%
Roof top >100 kWp	5%	10%	10%	9%
Ground mounted	6.5%	10%	10%	9%
	Degression	**2009**	**2010**	**2011**
Upper limit in MWp	above: +1%	1,500	1,700	1,900
Lower limit in MWp	below: -1%	1,000	1,100	1,200

continue to be the driver of the German PV market. For some more years not only will domestic installations depend on this successful support scheme, but a whole industry sector, many employers and a lot of Know-How would be at stake. Although Feed-in Tariffs will decrease faster than in previous years, the industry will do its best to keep pace with cost reductions in order to deliver competitive products.

Legislation

The German Feed in Law (EEG) has inspired many countries all over the world. This law has been the driver not only for the German PV industry, it has also shown the rest of the world that political commitment can help to achieve environmental goals and lead to industrial development at the same time. In June 2007 the German parliament decided to amend the EEG. Annual digression rates will increase as from 2009. Furthermore, there will no longer be a bonus for façade integrated systems. If the growth of the PV market (new installations) in a year will be stronger or weaker than the defined growth corridor, the digression in the following year will increase or decrease by one percentage point respectively.

Industry situation

The German industrial activity is impressive. About 10,000 companies are working in the PV sector (including installers). 80 of those are component producers such as cell and module producers. The industry turnover has reached €5.7 billion. The export revenues are summing up €2.5 billion. Approximately 42,000 people were employed thanks to an expanding industry. 842 MW of cells were produced only in Germany in 2007. For the creation and modernization €1.8 billion were invested and €175 million flew into research and development.

Spain

Market Situation in 2007

According to the most recent data from the National Energy Commission (Comisión Nacional de Energía), provisional figures only, in 2007, 512 MW were connected to the grid, reaching a total cumulative capacity of 655 MW.

Short term market outlook

During 2008, it is foreseen that until September about 1,000 MW will be installed, with the existing possibility that no further PV power plants will be installed during an indeterminate period. This situation will last until the solar energy sector adapts to the new legislative changes. For the coming years, due to the current undefined regulation, it is not possible to make a correct estimation. The associations of the sector are in the last stages of negotiations with the Government. These negotiations aim to define a new Royal decree in order to regulate the sector. It is clear that this power installations cap will be fixed, and that the first cap in 2009 will allow an installed capacity of between 300 and 500 MW. The posterior growth may vary between 10 and 20% annually. However, this situation could change within the next two years due to the development of an Energy Renewable Law and a new Renewable Energy Plan 2011-2020, foreseen within the current Government term.

Legislation

In the Spanish national context, there is currently a feed-in-tariff system for the PV on-grid installations and a grant system for off-grid systems (a market which constantly grows 2 MW per year). The Autonomous Communities have legal authority to establish additional support (for instance, for the installation in urban areas), but in a very limited way and irrelevant in any case.

Currently Spain lacks a target for photovoltaics. It had a 400 MW objective (371 MW on-grid) for 2010, but this was reached in August 2007. Now, the new royal decree has to establish new targets, at least, for 2009 and 2010 until the approval of the Renewable Energy Plan 2011-2020. The Spanish PV market has been focusing, so far, on ground-mounted installations, which represent 95% of the total installed capacity for 2007. The new royal decree should promote BIPV (Building Integrated PV) installations by clearly differentiated caps depending on the type of application (ground-mounted, roof-top and BIPV).

The new royal decree should simplify administrative procedures in order to allow the deployment of small PV installations in the residential sector; moreover, the grid access procedures must be clarified, especially where the distribution grid is concerned.

In cases with a low market volume, a limitation of ground-mounted installations might be established. This fact would avoid at the same time an excessive market concentration and the loss of a fundamental distributed energy source. Moreover, we should avoid a social rejection due to large power plants at a time where the population is not yet familiar with the technology.

Industry situation

The photovoltaic industry has been developing its own technology for the past 25 years. In the last few years, particularly in 2007, industrial development has grown tremendously with the entering into operation and announcement of numerous projects that will provide the Spanish market with products throughout the value chain. Spain remains one of the main producers of solar generators and is a worldwide leading competitor, therefore the market take-off has reduced the traditional weight that exports usually played on Spanish producers. Not only is the industrial capacity growing but also it is developing specifically its worldwide leadership in the field of concentrated photovoltaic technology for both research and production.

In 2007, over €5 billion were invested in the PV technology in Spain. This includes investment in new electricity production units (about 2,5 billion), investment in stock exchange (over 2 billion) and new manufacturing plants for equipment and components (over 500 million), from cells to inverters, tracking systems, and other elements of solar systems. The growth of industrial investments was even greater than the market development, the first multiplied by 5 in the last year, while the second quadrupled. In 2007, cells production in Spain represented about 145 MW (capacity was 360 MW) while module production was 195 MW (capacity was over 700 MW).

According to the Spanish PV industry Association (ASIF), there was about 26,800 direct and indirect employees in the PV sector in 2007, of which 25% in production, 65% in installation and 10% in other positions.

France

Market situation in 2007

For 2007, the French annual PV market was estimated at 35.5 MW. A considerable part of those installations took place in the French overseas regions (47% - 16.5 MW). In continental France 19 MW were in installed in 2007.

Short term market outlook

The French target for cumulative capacity for 2011 is 1.1 GW. Until 2020 the capacity should grow to 5.4 GW. The French PV market in 2008 will be between 150 MW and 200 MW presuming ongoing political commitment. This would mean that France maintains the feed in tariff (57 cts/kWh for BIPV and 31 €cent for non-BIPV) and for residential sector and below described the tax credit. In order to achieve the 2011 and 2020 target, the French support scheme need to be improved. Specific feed-in tariffs for semi-integrated PV and ground-mounted installations would be needed, modifications in the building code are necessary.

Legislation

Since 2004, the introduction of the 40% tax credit, French PV market is facing considerable growth. The increase of the tax credit from 40% to 50% in 2005 and to a greater extent the improvement of the feed in tariff in July 2006 allowed a rise in PV installations. The French support scheme is rewarding BIPV installation with a bonus of 26 €cent. This bonus is also leading to specialization in the French PV industry. Therefore this bonus can not only be seen as a tool for environmental but an industrial policy making.

Industry situation

Direct employment in the PV branch (manufacturing and installation of cells and modules) is estimated to 3000 full time jobs in 2007. It is estimated that the sector employs indirectly 500 additional jobs. In November 2007 the quality label 'QualiPV' was adopted. This label, related to the quality of installations for the residential sector, will help to structure the network of installers trained to the photovoltaic technology.

By 2012 the market could reach 2,4 billion euro, condidering current prices. This could create 13,000 direct jobs and 6,000 indirect jobs. It is estimated that electricity production from photovoltaic energy could surpass 1 TWh.

Italy

Market situation

Italy has introduced a feed in law for renewable energies in July 2005, and the last decree of February 2007 has developed the photovoltaic market. With the issue of the new Conto Energia the Italian PV market has risen to a cumulative capacity of 100 MW in 2007 of which 50 MW were installed only in 2007. It is expected to double its capacitity, reaching 200 MW by the end of 2008.

Currently the market sectors in Italy are private customers (40% in 2007) and commercial customers (38%). Of less relevance are agricultural and public costumers. However as many large-sized plants are currently planned in Italy, their share is expected to increase in the future. The strongest market segment in 2010 will be commercial costumers realizing medium-to-large rooftop plants. The expansion of these 2 segments will largely happen at the cost of private costumers.

Short term market outlook

The national target is 3,000 MW of rated power to be installed within 2016. For the current law, the limit of cumulative power of all PV plants is set at 1,200 MW. The Italian PV market has the potential to become one of the world's most important PV markets. The good climatic conditions and the availability of free land are supporting the development of PV.

Legislation

The feed in tariff is paid by GSE (Gestore dei Servizi Elettrici). The tariffs change according to the plant size and level of building integration. (See table below).

The lowest tariff of 0.36 €cent/kWh is awarded to non integrated systems bigger than 20 kW. Unlike the previous version of the Conto Energia, there is no restriction of the maximum size of this category. The highest tariff goes to systems between 1-3 kW which are architecturally integrated.

With the introduction of the new Conto Energia the basic feed in tariffs were slightly reduced especially for large sized ground-mounted systems. This was done because in the previous law big problems of speculation in connection with these systems types appeared.

The incentives still remain the same till the end of 2008 and are granted for 20 years. Starting from January 1st 2009 the rate will suffer a decrease of 2% till 2010 when a new law issued by the Minister of Economic D evelopment will determine new tariffs for PV plants starting their work after 2010.

The new law foresees a 5% increase of the feed in tariff in some special cases:

- **schools and public institutions receive**
- **municipalities < 5,000 inhabitants**
- **building integration PV in rural buildings**
- **building integration PV substitution of asbestos roofs**
- **self consumption of the produced electricity (>70%)**

Industry situation

The national turnover has increased from 25 million € in 2005 to 430 million € in 2007 creating new workplaces (220 employees in 1999 to 1.700 in 2007).

European Union

Thanks to its leading markets, the European Union remains the forerunner for PV.

Legislation

Proposed Directive on the promotion of the use of renewable energy.

On 10 January 2007, the European Commission announced in its Renewable Energy Roadmap that the EU indicative target of 12% renewables by 2010 'is unlikely to be met'. It therefore proposed to:

- **set a 20% binding EU target for renewables in gross inland consumption by 2020, with a specific minimum target of 10% for biofuels**
- **develop a new legal framework to strengthen the promotion of renewable energy sources.**

These targets were endorsed by the EU Heads of State at the European Summit of 8-9 March 2007. As a follow-up, the European Commission published on 23 January 2008 its Climate and Energy Package, including a proposal for a Directive on the promotion of the use of energy from renewable sources. This upcoming piece of legislation is crucial as it will repeal the existing Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources and set the future legal framework for renewable energies. EPIA considers that the proposal could foster a strong uptake of solar photovoltaic

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PV situation EU-27 (Policy driven scenario)				
	2007	**2010**	**2020**	**2030**
Annually installed capacity	1.7 GW	3.6 GW	16 GW	28 GW
Cumulative capacity	4.6 GW	13.5 GW	100 GW	360 GW
Electricity production in TWh	4.7	14	120	430
Grid connected people living on PV electricity for household needs (in millions)	3	9	80	280

electricity.The Directive, currently under discussion at European Parliament and Council should be finally adopted before the change of term of the European Parliament in the first semester 2009.

Strategic Energy Technology (SET) Plan

The European Commission published on 22 November 2007 a Communication on a Strategic Energy Technology (SET) Plan. The communication calls for strengthened cooperation at EU level to increase and improve investment in a broad portfolio of low carbon energy technologies. Included among the six European industrial initiatives proposed is the Solar Europe Initiative, which should focus on PV and concentrated solar power. This initiative represents a fantastic opportunity for the photovoltaic industry to join forces and foster market development and deployment. The official endorsement of the European Industrial Initiatives by the Heads of State is foreseen in Spring 2009.

Third Energy Package

The PV sector is also expected to be positively affected by the Third Energy Package on the liberalisation of the electricity market, currently under discussion at European Parliament and Council.

This Third Energy Package should ease cross-border investments and infrastructures and reduce fragmentation of national or regional markets. The proposed ownership unbundling should facilitate access to the grid for new entrants. The package, currently under discussion at European Parliament and Council, could be adopted by the end of 2008 under the French presidency of the European Union.

In addition, existing pieces of EU legislation relevant to the PV sector are currently under review, such as the Directive on the restriction of the use of Hazardous Substances (RoHS) and the Directive on Waste of Electric and Electronic Equipment (WEEE). Proposals for review are expected from the European Commission in autumn 2008 this year to be examined in the European Parliament and Council in 2009. It will be crucial to ensure that the PV sector, which is currently not included in the scope of these Directives, remains outside the scope in order to avoid additional administrative and financial burden.

A recasting of the Energy Performance of Buildings Directive (EPBD) is scheduled to take place in 2009. This will represent an opportunity to strengthen the promotion of BIPV and PV installed on buildings.

Last but not least, the photovoltaic companies will need to secure the supply of their critical raw materials in good contact with their suppliers, to ensure all relevant materials have been registered and fully comply under REACH, the EU regulation on the registration, evaluation, authorisation and restriction of chemicals.

United States

Market situation in 2007

The U.S. PV market saw a 48% growth in grid-tied installations in 2007, for total (grid-tied and off-grid) installations of over 190 MW. This brings the cumulative U.S. PV installed capacity at year end to approximately 750 MW.

California was still by far the dominant state with nearly 60%of PV installations, but installations in the rest of the U.S. grew by 83%. While some states have passed aggressive new renewable portfolio standards and optimized existing RPS programs to better deploy solar, news at the federal level has been less encouraging. The market faced uncertainty in 2007 due to Congress' failure to pass an extension of the solar Investment Tax Credit (ITC).

Short term market outlook

There is a high level of confidence that the ITC will be extended by the end of 2008 or in early 2009. Assuming the ITC is in place, the U.S. PV market is anticipated to grow over 65% annually for the next five years, with an expectation of over 10 GW of PV being installed by 2013. Those states that have shaped their RPS programs and other state policies to favor solar will see significant gains in both PV installations and job growth.

Additionally, the Solar America Initiative will be nearing its 2015 goal of bringing the cost of PV down to price-parity with conventional generation. The main drivers in the U.S. PV market will continue to be the federal tax credits, state RPS and net metering provisions, and continued federal funding for research and development.

Legislation

The most important legislative priority for the U.S. PV industry is the extension of the ITC, which is due to expire at the end of 2008. Without a long-term extension of the ITC, the industry will have to brace itself for scrapped projects across the country, billions of dollars in lost investment, and tens of thousands of jobs will be at risk. The industry hopes to avoid the on-again-off-again tax credit experience which hurt the development of the wind industry in the U.S.

Also, a national RPS was passed in the U.S. House of Representatives in 2007, but failed to pass the Senate. The U.S. PV industry would benefit from a federal RPS that encourages technology diversity (by means of a solar carve-out) and does not preempt more progressive state programs. The legislation will likely be reintroduced in 2009.

Climate change legislation was also introduced in 2008 that would have established a hybrid cap-and-trade system. This was the first major foray by the Congress into dealing with climate change. Any legislation hoping to meet the necessary stabilization goals will need to optimize the deployment of PV, taking advantage of the potential for small distributed generation as well as utility-scale PV installations.

Industry situation

While PV production grew in all areas of the U.S. market, the biggest development has been thin-film technology in which the U.S. is the global leader, accounting for nearly half of the world's production. With silicon prices anticipated to begin falling with increased production, extensive growth in all areas of U.S. PV production are expected.

The U.S PV industry currently employs about 50,000 people and it is expected that the coming boom in both manufacturing and installation will bring many more thousands of jobs to the industry.

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Japan

Japan's policy and measures on energy including PV power generation is based on the Basic Act on Energy Policy (Energy Policy Law) enforced in 2002, that stipulates 3 principles; securing a stable supply, environmental suitability and utilization of market mechanisms.

Market development

Through the measures for introducing PV Systems, mainly implemented by METI, the market development of residential PV Systems and PV Systems for industrial and public facilities is underway.

The size of the residential PV market grew to the level of 50,000 systems/year through government support programs for introducing residential PV systems implemented for 12 years. Cumulative installed capacity at the end of FY2006 was 1,277 MW installed at approximately 350,000 houses. Even after the program was completed, the PV market in Japan didn't shrink but leveled off. PV manufacturers are working on expansion of the market for residential PV Systems for both newly built and existing houses by minimizing the price increase of PV Systems despite the soaring price of silicon feedstock due to the polysilicon shortage. In the newly built residential house market, pre-fabricated house manufacturers enhance efforts for energy conservation and reduction of CO_2 emissions. Accordingly, some housing manufacturers adopted PV Systems as standard equipment and this trend has expanded to major housing companies, who are advertising PV-equipped housing on TV commercials to increase sales across the country. In particular, the new concept of zero-utility charge house equipped with PV system contributes to the expansion of purchasers who recognize economical efficiency in running cost of the house as well as the environmental value. In the PV market for existing houses, PV manufacturers are developing and establishing a distribution channel consisting of local builders, electric contractors, electric appliances stores and roofers, etc., while seeking purchasers of residential PV systems all over Japan. Through the long-term field test projects, PV systems for nonresidential use, such as for public and industrial facilities, have been making progress year by year in many aspects: economical efficiency, grid-connection technology, design and installation as well as system efficiency. Consequently, opportunities for market expansion have been increasing and diversified in such areas as application, design, installation sites, power generation capacity and introducers of PV Systems and the market development of non-residential area is in progress. As for the installation sites, PV Systems have been added to a wider variety of places: public facilities (schools, government office buildings, community buildings, water purification plants, welfare and medical facilities) and industrial facilities (factories, warehouses, laboratories, office buildings, commercial buildings).


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In addition to these sites, recently, PV systems have been installed to agricultural facilities (greenhouses), commercial facilities (shopping malls, family restaurants), railway facilities (station buildings and platforms), road facilities (parking lots and expressway toll booths), financial facilities (banks, etc.), transport facilities (logistics centers, etc.) and resort facilities (hot-spring resorts, etc.). The size of a PV Systems has been increased to as large as 5 MW. The range of those who installed PV systems are widely varied, from large companies to individual owners in the private sector and from public-interest organizations to nonprofit organizations (NPOs). Some companies have been introducing PV systems to their factories and offices nationwide and installing additional PV systems to existing PV-equipped facilities. Installation of large-sized PV systems is also on the rise. The number of such companies has been increasing year by year. In NEDO's Field Test Project on New Photovoltaic Power Generation Technology in FY2007, total capacity exceeded 20 MW, of which

2,007 kW was installed by Toyota Motor Corporation and 1,000 kW by Electric Power Development.

Future outlook

The government of Japan revised the Basic Energy Plan foreseeing around 10 years ahead in 2007. The Plan emphasizes the importance of energy security reflecting recent global circumstances such as the tight situation of energy demand and supply, soaring prices of energy and countermeasures against global warming. The main pillars of the Plan include the following:

1. **promotion of nuclear power generation and expanded installation of new and renewable energy,**
2. **aggressive development of diplomacy on resources toward the stable supply of fossil fuels such as oil,**
3. **enhancement of energy conservation strategy and initiative for forming an international frameworks to work on measures against global warming and**
4. **strengthening of technological capabilities.**

New and renewable energy is positioned as 'the complementary energy for the time being; which the government will promote measures aiming at making new and renewable energy one of the key energy sources in the long run.' For that, the government announced the creation of strategic efforts for implementing technological development to reduce costs, to stabilize the grids and to improve performance in collaboration among industrial, academic and governmental circles. Furthermore, in order to expand introduction of new energy, the following measures are included, depending on different stages of market growth:

1. **take-off support (technological development, demonstration tests),**
2. **creation of initial demands (model projects, support for installation of facilities),**
3. **initiative in installations (at public institutions-related facilities),**
4. **support for market expansion (legal actions such as the RPS Law),**
5. **formation of industrial structure (promotion of venture businesses to enter into the market, fostering peripheral and related industries),**
6. **maintenance of promoting environment for dissemination (awareness for dissemination, public relations and information service).**

In addition, the government reviewed the RPS Law which obliges utilities to use a certain amount of new energy, and set the target for the period between FY2011 and FY2014. In the revision, final target for FY2014 was set based on the former target of 12.2 billion kWh by FY2010 as a benchmark, by increasing 950 million kWh every year, to reach the ultimate goal of 16 billion kWh. The revision adopted a special preferred measure to double-count the RPS equivalent volume for PV power generation in order to improve the system management of the RPS Law. It is expected this measure would be a new tailwind for the dissemination of PV Systems.

Moreover, the government proposed a long-term target of countermeasures against global warming; cutting global greenhouse gas (GHG) emissions by half from the current level by 2050, announced 'Cool Earth 50 - Energy Innovative Technology Plan' to achieve the target and selected 20 research topics to be promoted as priorities. 'Innovative PV Technology' was selected as one of the research topics aiming to improve conversion efficiency of solar cells from current 10-15% to over 40% and reduce power generation cost of solar cells from current 46 Yen/kWh to 7 Yen/kWh. The efforts for 'innovative PV technology' will start from FY2008.

Meanwhile, it is assumed that the PV manufacturers will enhance their efforts for full-scale dissemination of PV Systems by working on **1)** further cost reduction of the PV system, **2)** detailed product development suitable for each application area, and **3)** development of new application area, through technological development, enhancement of production capacity and collaboration with other industries using PV Systems.

Thus, in addition to these efforts by the national government and industry, and with support from users of PV Systems, including other ministries, agencies, local authorities, private companies and individuals, further deployment of PV Systems in Japan will continue into the future.

(IEA-PVPS, Annual Report 2007)

South Korea

Market situation in 2007

The cumulative installed power of PV system in Korea increased to 77,6 MW by the end of 2007. Annual installed power in 2007 was 42.9 MW, which was more than two times higher than that achieved in the previous year (21.2 MW).

Short term market outlook

Due to the 100,000 rooftop program, the favorable feed-in-tariff scheme and other promotion measures, the Korean PV market will to continue to grow quickly. The major market resides in PV for residential houses and buildings and large-scale PV plants connected to electricity grid.

Legislation

The Feed-in Tariff rate per kWh was 677,38 KRW and 711,25 KRW for systems larger and smaller than 30 kW, respectively. The support scheme has a ceiling of 100 MW cumulative since October 2006 and the tariffs are guaranteed for 15 years for PV systems over 3 kW. A modified feed-in-tariff scheme will be applied from October 2008.

Under the 100,000 rooftop Program, the Government supports 60 % of the total system price for single-family houses and 100 % for public rent apartments. Public Building Obligation Program: New public buildings larger than 3,000 sq meter must spend 5% of total construction budget in installing renewable facility including PV. The South Korean deployment target for PV is 1,3 GW by the year 2012.

Industry situation

In 2007, there was only one solar cell producer in Korea, producing 25 MW of PV cells with an annual production capacity of 36 MW. Around ten companies produced PV modules of 53 MW with an annual capacity of around 190 MW. There are also several BOS manufacturers as well as around hundred system installers. About 1,600 employees can be found in the manufacturing, installation and public sector.

All in all the South Korean PV market is developing very positively and in order to reach the target by 2012, growing annual market figures can be expected.

China

Market situation in 2007

By the end of 2007, cumulative installed capacity of solar PV in China is 100 MWp.

Annual installed in 2007 is 20 MWp.

So far, only 6% of solar PV installed are on-grid ones. The biggest application of solar PV is on rural electrification.

Short term market outlook

By 2010, cumulative installed PV capacity will be 300 MW. Further development will happen between 2010 and 2020, and by 2020, cumulative installed capacity will be 10GW. Permission of large-scale PV power station and encouragement of on-grid rooftop systems would be the key market drivers.

Legislation

Under 2006 Renewable Energy Law,

- Both building-integrated PV systems and large-scale desert PV power plants will be subject to the 'feed-in-tariff' policy.
- For off-grid central PV power plants in villages, the initial investment will be paid by the government, and the portion of the cost of subsequent operation and maintenance that exceeds the revenue from electricity fees will be apportioned to the nationwide electricity network by increasing the electricity tariff.
- End-users, whether grid-connected or off-grid, will pay for their electricity according to the 'same network, same price' principle: in other words, the electricity tariff paid by PV power users will be the same as the electricity tariff paid by grid-connected power users in the same area.

However, there still exists many difficulties in implementing support policies for solar PV. Firstly, for grid-connected PV, a dozen PV power systems have been installed, with capacities ranging from several kWp up to 1 MWp. However, in no case has a feed-in tariff, calculated according to 'reasonable costs plus reasonable profits', been implemented and no PV power system has as yet been permitted by grid companies to connect to the grid. No project has been built by developers for commercial operation.

The Renewable Energy Law is proving more difficult to execute for PV. For off-grid PV, although the Renewable Energy Law and regulations have made it clear that the cost should be apportioned across the whole network for the subsequent operation and maintenance of PV plants (more than 720) that were built under the Township Electrification Programme, the transfer of these power plants has not yet been completed.

Although the warranty period of three years has expired, maintenance is still being carried out by the constructors (system integration enterprises). The annual maintenance cost is about Yuan 4,000 per kWp, and these outlays have not been settled so far. A mechanism needs to be urgently developed to incorporate the renewable electricity tariff into the national electricity network so the accumulated funds can be used for the operation and maintenance of rural PV plants according to the principle of Renewable Energy Law. Otherwise these plants, which were built with an investment of several thousand million Yuan, will become redundant. Such a problem will also face the phase of the Township Electrification Programme which is about to be implemented.

National RE target: by 2010, RE accounts for 10% of the total energy consumption; by 2020, it will account for 15% of the total. By 2010, installed capacity of solar PV will be 300 MW; and by 2020, that will be 1,800 MW. Solar PV application will be mainly concentrating on rural electrification, rooftop PV system in urban areas and large-scale PV power station in desert areas.

For a successful solar energy market, there are several key policy measures needed:

- To set bold targets to encourage local producers' investment and reduce costs;
- To establish supportive pricing mechanisms. A reasonable tariff and smooth operation should be the two criteria for a good pricing system;
- To prioritize reform of the energy structure. Substitute traditional energies with new energies, replacing energy from scarce resources with energy from more widely available resources and replacing fossil fuels with renewables.

Industry situation

Polysilicon production in China is 1,130 tons for 2007. Only 6 producers are active in polysilicon production, that is, Emei, Luoyang Zhonggui, Sichuan Xinguang, Xuzhou Zhongneng, Wuxi Zhongcai and Shanghai Lingguang. There are more than 70 manufacturers in silicon ingot manufacturing industry. Total production in 2007 is 21,400 tons per year. In 2007, total PV panel production in China is 1,088 MWp, listed as world number 1 PV manufacturing country. There are more than 50 PV panel producers. Top 5 are Suntech, Yingli, Hebei Jingao, Jiangsu Linyang, and Nanjing CEEG.

Total employment created by PV industry in 2007 is 82,800, 6 times that of 2005.

Australia

Market situation in 2007

By the end of 2007, cumulative installed capacity of solar PV in Australia was 82 MW.

The annual installed capacity in 2007 was 12.2 MW. Grid systems accounted for 50% of installations and now account for 18% of installed capacity. The biggest applications are off-grid non domestic (38.7 MW) followed by off-grid domestic (25.9 MW).

Short term market outlook

There are no specific PV targets in Australia. However, the Renewable Energy Target has been increased to 45,000 GWh by 2020, which will provide some support for PV in the near term and possibly more support in future as the target gets harder to meet with other renewables and PV prices fall. The new Australia Government has a greenhouse gas reduction target of 60% by 2050 compared with year 2000 levels, so the market for PV and other renewables will increase with time.

Legislation

AU$ 7.44 million were spent on PV research and development by State and Federal Governments in 2007, up slightly from last year. However, there was a significant increase in spending on demonstration, AU$ 3.72 million, while expenditure on market stimulation doubled to AU$ 53.53 million.

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Policy initiatives

In November 2007 a new Labor Government was elected in Australia. It has ratified the Kyoto protocol, has pledged to increase the Renewable Energy Target from its current level of 9,500 GWh by 2010 to 45,000 GWh by 2020, to substantially increase the Solar Schools program and to add two new Solar Cities. Most of these initiatives have not yet begun, although some details will be provided later in the report. The following therefore describes existing activities which impacted on the PV market during 2007.

The most important new driver for the PV market in 2007 was a doubling of the residential grant from the PV Rebate Program from AU$ 4,000 to AU$ 8,000 for the first kW installed. This was introduced in May and resulted in significant market growth for the second half of the year, the establishment of many new businesses and a marked increase in PV installer accreditation. AU$ 150 million was allocated to the program over 5 years, including funding for school and community PV systems, which were eligible to apply for 50% of system costs for up to 2 kW. System installations increased from an average of 300 per month to over 1,000 with the higher grant and other incentives resulting in payback times of around 20 years or less, and hence attracting a much broader customer base. A total of 4.6 MW of PV was installed under the PV Rebate Program in 2007, up from 1.8 MW last year. In 2008 the government introduced a means test to reduce demand and keep within its budget limits.

The second important policy driver was the increased interest in feed-in tariffs. The Northern Territory Power and Water Authority, as part of the Alice Springs Solar City, is offering an AU$ 0.45/kWh tariff for all electricity generated from the 225 homes being supported through the program. This is about twice the daytime electricity tariff and the buyback is capped at AU$ 5 per day (effectively limiting the tariff to 2 kW systems). With the grants and tariffs, system costs are expected to be repaid within 10 years. The South Australian and Queensland governments announced new net export feed-in tariffs of AU$ 0.44 and the Victorian government AU$ 0.66.

The Australian Capital Territory is considering a total export model set at 3.88 X standard tariffs, with the aim of paying back system costs within 10 years. The national government has indicated an interest in a uniform PV feed-in tariff across Australia and is undertaking a review of State, utility and international programs.

Promotional activities (commercial and non-commercial)

The increased PV rebate stimulated competition in the market, as well as new marketing ideas. The latter included bulk purchase options offering 1 kW systems for AU$ 1,000 or less, if 50 or more homes were involved.

A range of promotional activities, including energy fairs, mailouts and internet based special offers, have been rolled out by the various Solar Cities (see below). This has greatly increased awareness of PV in the target communities. This interest will be reinforced over the coming years as an increasing number of high profile community PV systems, as well as more residential systems, are installed in the Solar Cities.

Other new drivers

With the high rebates, PV began to enter the mainstream retail market, with large hardware stores, builders, as well as solar shops and local governments selling or promoting PV. This will increase public awareness and also improve competition over time. It is also improving the ease of purchase as well as the range of system and financing packages available. Several companies offer combined solar water heating and PV packages.

There has been a noticeable increase in the number of PV systems installed on commercial and public buildings as part of corporate or government green building or greenhouse gas reduction programs. This trend is expected to continue as Solar City installations begin, building energy standards improve and energy prices increase due to international resource prices, infrastructure upgrades and emissions trading.

Electricity utility and public stakeholder developments

Several electricity utilities offered feed-in tariffs, most net export, but one offers a gross generation feed-in tariff for a selected customer base.

In line with government mandates, electricity utilities are beginning to change over to electronic ‘interval’ meters, which in turn allow for the introduction of use time tariffs. The relevance of this for PV depends on the tariff structure. For instance, Energy Australia offers a feed-in tariff for PV systems of AU$ 0.28. However, this tariff applies only between 2pm and 8pm, which would favour west facing arrays. In Sydney, a west facing array would produce around 25% less electricity over the year than a north facing array.

Industry situation

PV production in Australia remained steady at 36 MW of cells and 9 MW of modules produced by BP Solar. There is only one module manufacturer in Australia – BP Solar. Solar Systems manufactures concentrator PV systems using imported cells, but is in the process of setting up cell manufacture in Australia. BP Solar produces its own cells from imported wafers. 75% of cells produced at the BP Solar Sydney plant are exported and 52% of modules. In 2007, standardisation of products continued and larger kit systems were marketed. Improved anti-reflect coatings on glass were introduced.

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Greenpeace is an independent global campaigning organisation that acts to change attitudes and behaviour, to protect and conserve the environment and to promote peace by:

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