> Competitiveness

# Solar Generation IV – 2007

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

GREENPEACE

EPIA
European Photovoltaic Industry Association

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## Contents

**Greenpeace and EPIA are joining forces** for the fourth time to publish a report on PV solar electricity: Solar Generation IV. Apart from providing an overview of the current worldwide status of PV in terms of policy, technology and economics, Solar Generation contains credible scenarios which prove once again that PV is clearly on the way to becoming a well established energy source in the coming decades.

Since the last edition of Solar Generation was published in September 2006, a different light has been shed on the global potential for renewable energy. A window of opportunity has opened up. Awareness of renewable energy has never been so great, triggered by a number of landmark events:

- The Intergovernmental Panel on Climate Change (IPCC) published its latest report, in which it warned the global community more strongly than ever of the drastic consequences of climate change.

- The Stern Report made clear that every dollar invested in climate change mitigation will pay off by avoiding much more drastic negative economic impacts at a later stage.

- The European Commission has put forward an ambitious target for 20% renewable energy by 2020 in Europe's overall energy mix, whilst the US is also starting to green its energy policy.

# Foreword

In the light of these developments, Solar Generation IV provides valuable information for stakeholders in the global renewable energy community. The socio-economic and environmental benefits are once again underlined by the publication's subtitle: **Electricity for over 1 billion people and 2 million jobs by 2020.** This report is a practical blueprint to achieve these goals.

For the first time in the Solar Generation series, three different scenarios for future PV development are used.

The **Advanced Scenario** shows a PV future which can be achieved with adequate political commitment at a global level. EPIA and Greenpeace strongly believe that this is possible. Although the scenario shows that 10% of global electricity consumption could be met by PV in 2030 (28% in 2040), the potential of PV could be even higher than that.

The **Moderate Scenario** describes a future that is less bright. Weaker political commitment in the next few years would slow down PV development in the longer term.

Finally, the **IEA Reference Scenario**, based on projections by the International Energy Agency, is the least sustainable for the future energy mix and should by all means be avoided. Recent PV growth rates have already exceeded its expectations. It is in the hands of the readers of Solar Generation to prove that it will continue to be wrong in the future.

**EPIA**
Dr. Winfried Hoffmann
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 2006 the cumulative installed capacity of solar photovoltaic (PV) systems around the world had reached more than 6,500 MWp. This compares with a figure of 1,200 MWp 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 € 9 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 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, 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: 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 retailing 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 Japan and Germany, 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 | | | | |
| SG I 2001 aMW | 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 | | | | | | 1883 | 2,540 | 3,420 | 4,630 | 5,550 |
| SG IV 2007 MW | | | | | | | 2,179 | 3,129 | 4,339 | 5,650 |

This scenario for the year 2030, together with an extended projection forwards to 2040, 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 2006). An alternative version is based on the Greenpeace/European Renewable Energy Council Energy Revolution 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 three 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 and a *Reference Scenario* based on the conservative assumptions of the IEA. The growth rates assumed in these scenarios vary from 40% reducing to 15% over the scenario period under the *Advanced version*, 30% reducing to 12% under the *Moderate version* and 16% reducing to 10% under the *Reference version*.

The three 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 |
|---|
| 6.4% of global electricity demand under *IEA reference scenario* |
| 9.4% of global electricity demand under *alternative scenario* |

| Global Solar Electricity Output in 2040 |
|---|
| 20% of global electricity demand under IEA reference scenario |
| 28% of global electricity demand under *alternative scenario* |

| Detailed Projections for 2030 | |
|---|---|
| PV systems cumulative capacity | 1,272 GWp |
| Electricity production | 1,802 TWh |
| Grid-connected consumers | 776 million |
| Off-grid consumers | 2,894 million |
| Employment potential | 6.33 million jobs |
| Market value | €318 billion per annum |
| Cost of solar electricity | €.07 - .13 per kWh depending on location |
| Cumulative $CO_2$ savings | 6,671 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 1,800 TWh of electricity around the world. This means that, assuming that 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 9.5 % of the world's population.

The capacity of annually installed solar power systems would reach 179 GWp 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 776 million.

Although the key markets are located now mainly in the industrialised world, a global shift will result in a significant share – about 27 % or an annual market of 48 GWp – being taken by the developing world in 2030. Since system sizes are much smaller and the population density greater, this means that up to 2.9 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.

By 2040, the penetration of solar generation would be even greater. Assuming that overall global power consumption had by then increased to 22,516 TWh (assuming serious energy efficiency measures), the solar contribution would equal 28% of the world's electricity output. This would place solar power firmly on the map as an established energy source.

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

For the solar production industry, global annual shipments of PV modules are projected to rise from 1,467 MWp in 2006 to more than 179 GWp in 2030. 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, more than 6.3 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 just over 1 billion t. This reduction is equivalent to the 2004 emissions for the whole of India, or the output from 300 coal-fired power plants. Cumulative $CO_2$ savings from solar electricity generation would have reached a level of 6.6 billion t.

## Policy Recommendations

In order to supply more than 3 billion people with solar electricity by the year 2030, and go on to achieve a global electricity share of 28% by 2040, 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 179 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. By 2008 these new factories should 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.

### 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 produce 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 kWp 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 kWp 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?

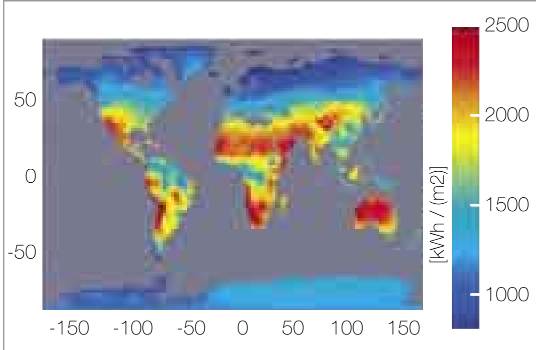
Many producers give performance warranties of 20-25 years for their modules. At the EC Joint Research Centre in Ispra (Italy) crystalline modules have been operating in a field test, with excellent performance results, for more than 20 years. The majority of the modules continue to exceed 92% of their 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 kWp system based on crystalline modules needs about 23 $m^2$ of a sloped roof area facing approximately south.

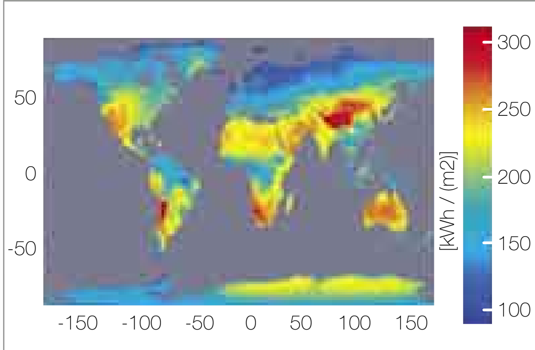
# Part One:
# Solar Basics

**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 at 566 sites is published and assessed by the European Joint Research Center (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*

## 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.

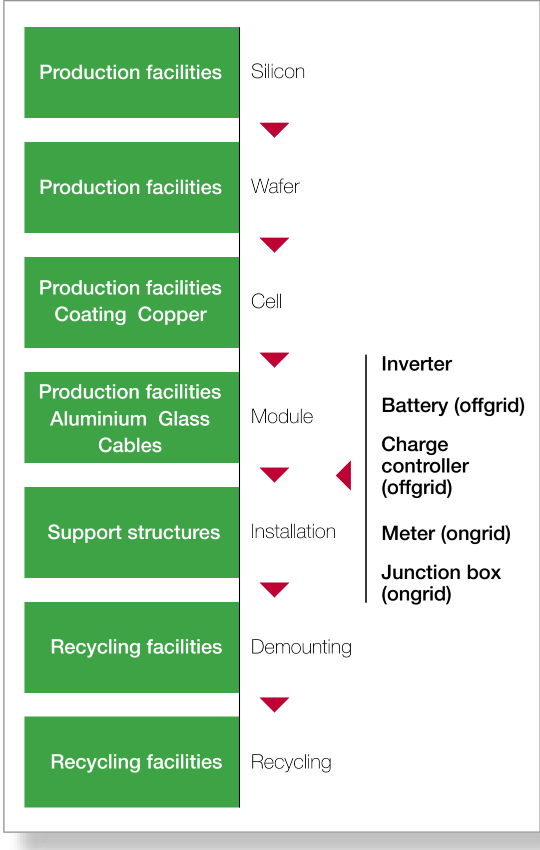
A photovoltaic system therefore does not need bright sunlight in order to operate. It can also generate electricity on cloudy days. Due to the reflection of sunlight, days with slight cloud can even result in higher energy yields than days with a completely cloudless sky.

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: Life cycle 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 (93% in 2006) 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.

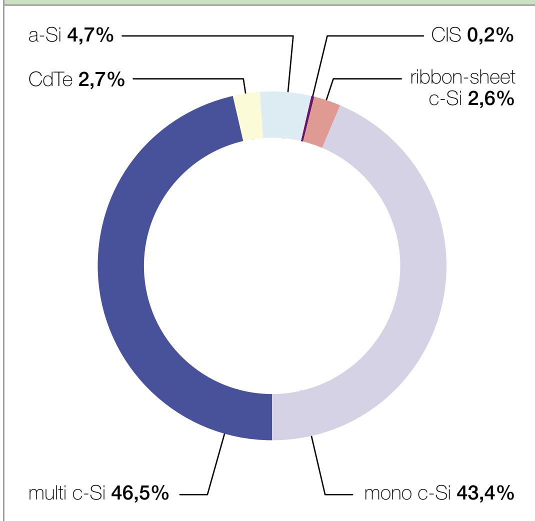
### Crystalline silicon

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 0.18 mm by 2007. 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 17.5%.

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 2006**




Source: Photon International, March 2007

### Thin film

Thin film modules are constructed by depositing extremely thin layers of photosensitive materials on to 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 counterbal-anced at the moment 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

*Large PV Power Plant with Solar Trackers located in Castejon, Spain*

| **Table 1.1: Module and cell efficiencies** | | | | | | |
|---|---|---|---|---|---|---|
| **Technology** | Thin Film | | | | Crystalline wafer based | |
| | *Amorphous silicon (a-si)* | *Cadmium telluride (CdTe)* | *CIS* | *a-Si/m-Si* | *Monocrystalline* | *Multicrystalline* |
| **Cell Efficiency at STC*** | 6-7% | 8-10% | 10-11% | 8% | 16 –17% | 14 – 15% |
| **Module Efficiency** | | | | | 13 – 15% | 12 – 14% |
| **Area needed per kWp** (for modules)** | 15m² | 11m² | 10m² | 12m² | app. 7 m² | app. 8 m² |

* Standard Testing Conditions: 25°C, light intensity of 1,000W/m², air mass = 1.5
** kWp = kilowatt 'peak'. Solar PV products and arrays are rated by the power they generate at Standard Testing Conditions

substrate, for example stainless steel, is coated in a continuous process with layers. 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 4.7% of the total market in 2006.

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

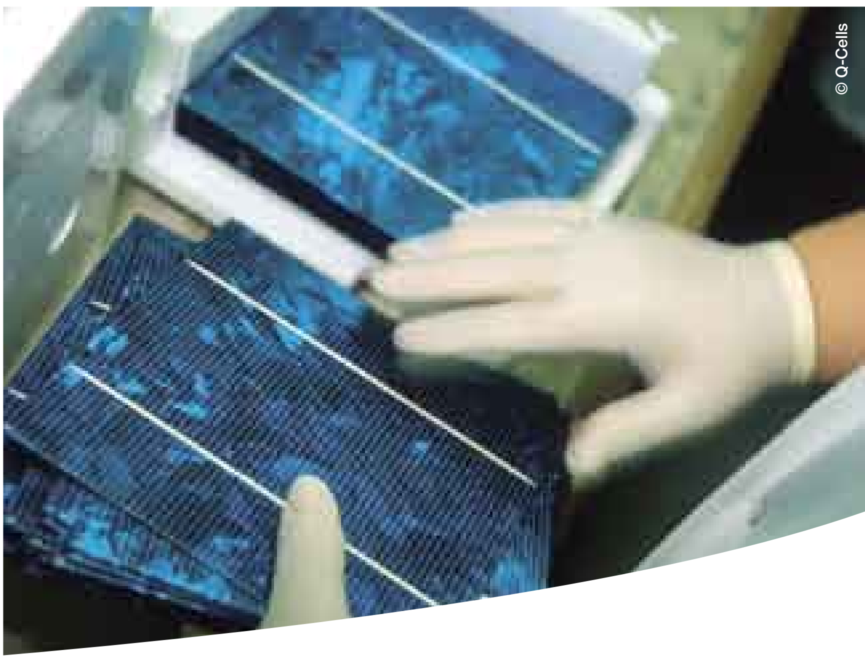
**Concentrator cells** work by focusing light on to a small area using an optic concentrator such as a Fresnel lens, with a concentrating ratio up to 1,000. The small area can then be equipped with a material made from III-V compound semiconductors (multi-junction Gallium Arsenide type), which have efficiencies 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 exactly 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 kWp (peak), this refers to the output of the system under standard testing conditions (STC), allowing comparisons between different modules. In central Europe a 3 kWp 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.

*Multicristalline 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 kWp (3-6 kWp) up to central inverters for large-scale systems with 100 kWp 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.

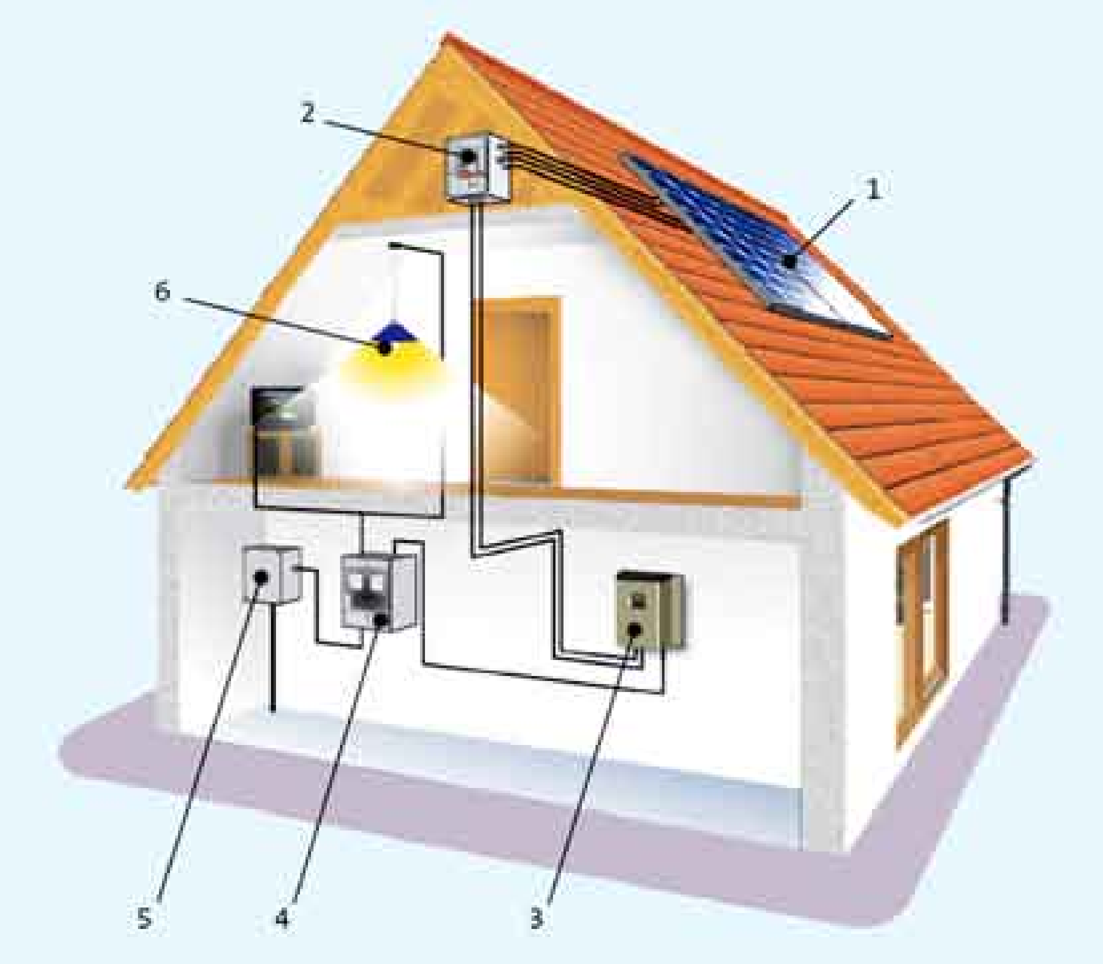
***Off-grid***

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<br>2 PV array combiner / junction box<br>3 Grid tied inverter | 4 Import / Export meter<br>5 Connection to the grid<br>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 2006 the cumulative installed capacity of all PV systems around the world had surpassed the landmark figure of 6,500 MWp. This compares with a figure of 1,200 MWp 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 € 9 billion in 2006. 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. Consumer 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*


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 2006 this sector accounted for roughly 2% 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 kWp 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 MWp) represent about 10% of the European PV market. Those systems are particularly suitable in areas where there is no competition from other land use demands. Such large plants solely function 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 85% by 2006.

A growing number of countries have followed the successful examples of Germany, Japan and 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

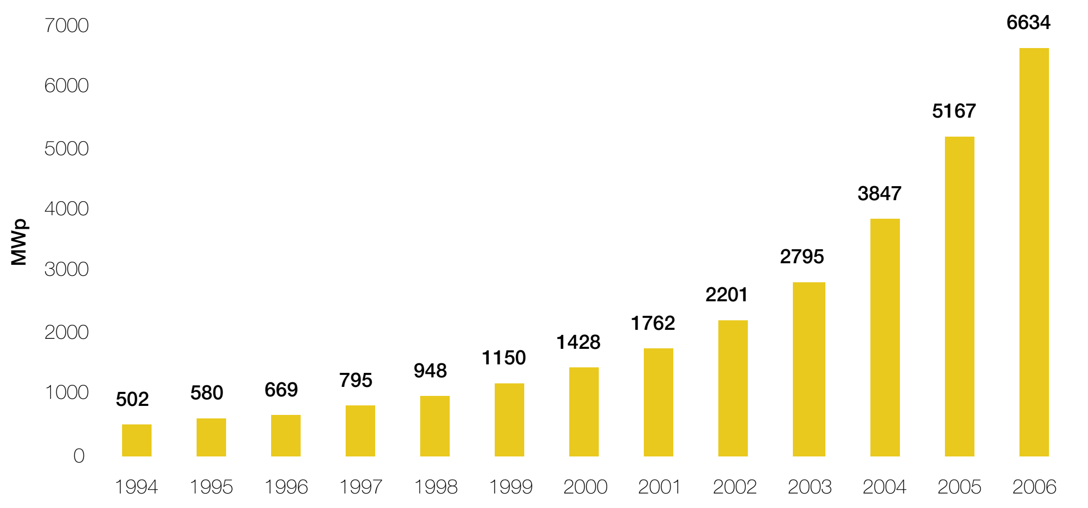
***Applications***

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 itself.

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*

**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 2006 approx. 7% of the 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 waste water treatment plants.

**Figure 2.2: Global annual PV market**

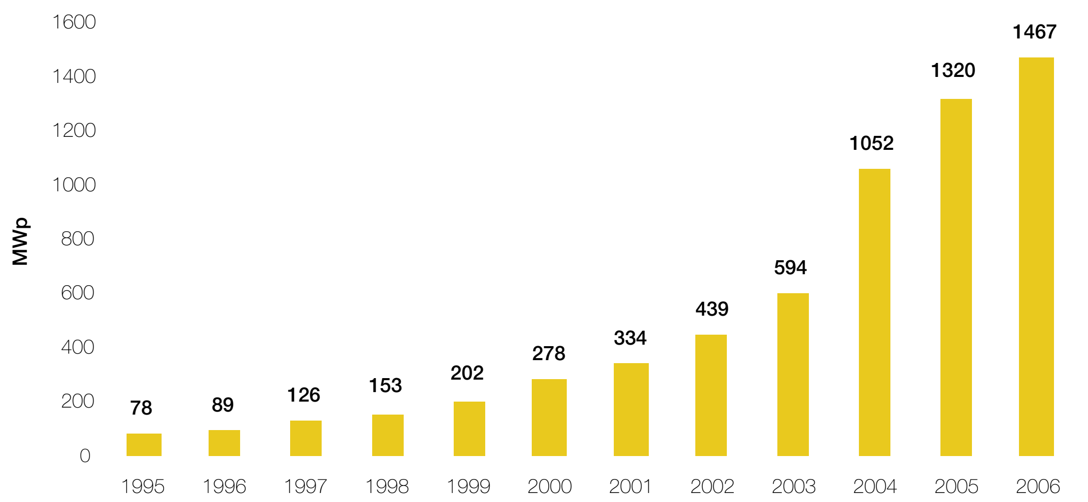
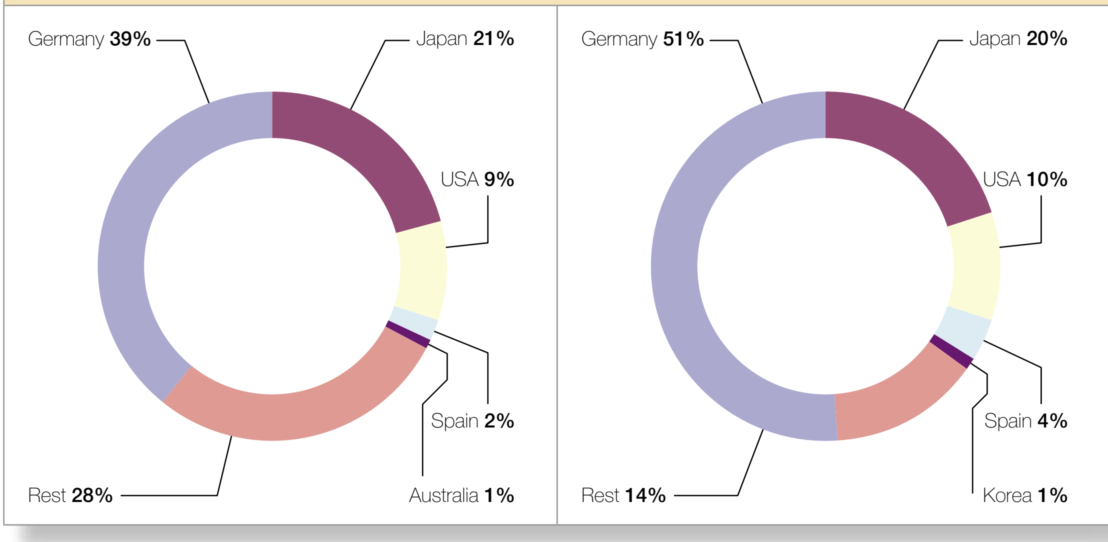



**Figure 2.3: Top 5 PV country markets**




| Top 5 Total installed capacity 2006 (MWp) | | Top 5 New capacity 2006 (MWp) | |
|---|---|---|---|
| Germany | 2530 * | Germany | 750 * |
| Japan | 1708 | Japan | 290 |
| USA | 620 | USA | 141 |
| Spain | 120 | Spain | 63 |
| Australia | 70 | South Korea | 21 |

* estimate

***Market development***

Apart from avoided fuel costs, for example by totally or partly replacing a diesel engine, 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 7% of global PV installations were used for PV industrial off-grid applications in 2006.

## Supply Side Market - Manufacture

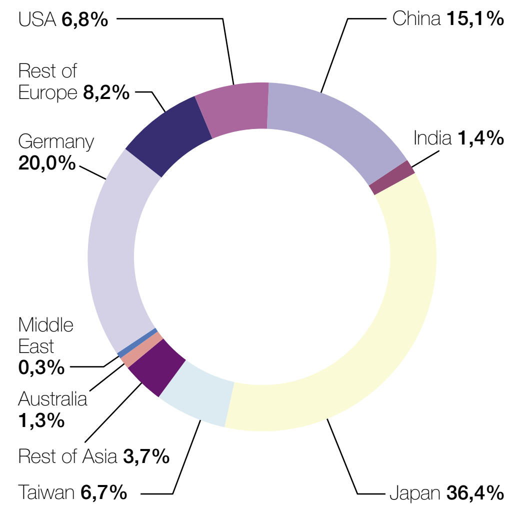
### Solar grade silicon

Silicon is the basic material required for the production of solar cells based on crystalline technology – 93% 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 semiconductor 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 semiconductor industry. With the dynamic growth of the PV industry in recent years, however, the situation has changed. In 2006, approximately 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 semiconductors, and can therefore 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 semiconductor industry for the currently limited supply available on the market.

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




Source: Photon International

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 2007 and 2010 it is projected that more than €4 billion will be invested in upscaling silicon production capacities.

### Solar cell and module production

In 2007 the level of investment in new plants to manufacture solar cells and modules is expected to exceed €1.2 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.

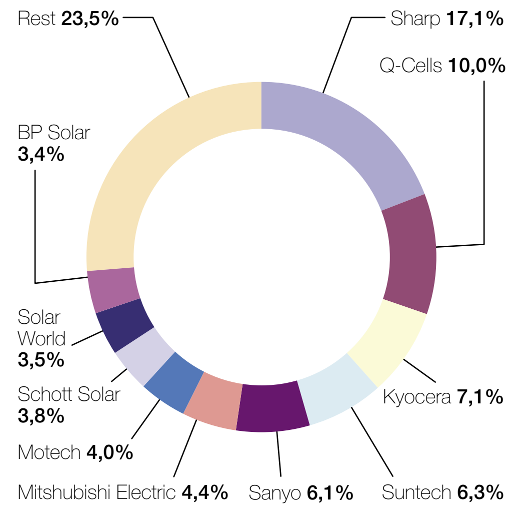

*Aerial view of the German Parliament with PV modules integrated on the roof*

Up to now the manufacture of solar cells and modules has been concentrated in three key geographical areas – Europe, Japan and the United States. Ho wever, 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 17.1% in 2006. Just over 75% of all cell production is handled by the 10 biggest companies; 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 MWp in 2001 to around 500 MWp in 2006.

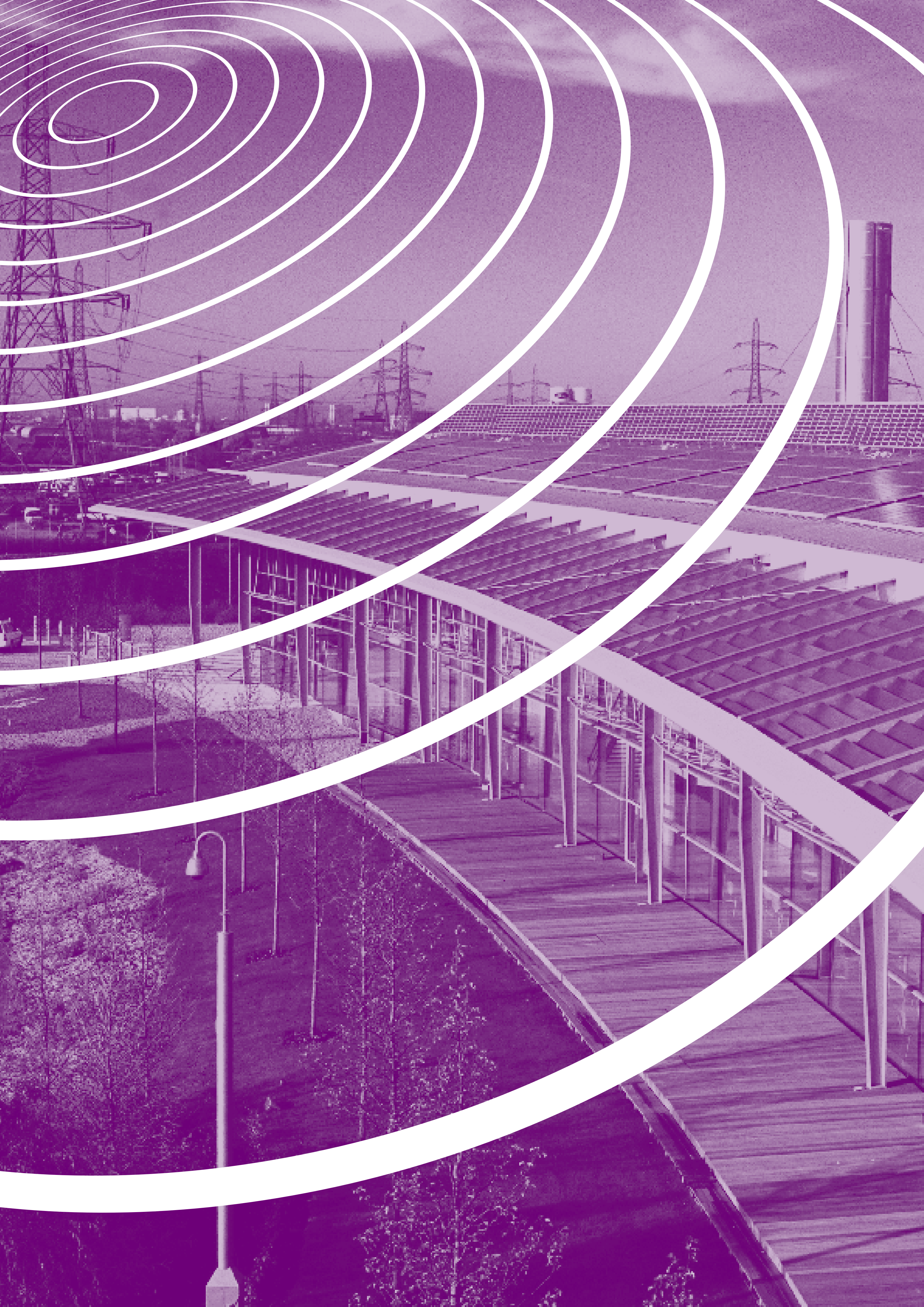
**Figure 2.5: Top 10 PV cell producers**




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 least 42 wafer, cell or module producers joined the market in 2006, taking the total number of companies involved up to a minimum of 150. This figure also only takes into account companies with capacities greater than 10 MWp. 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).*

The three 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**

*PV Cell production process*


### 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 | 23% |
| Average growth rate 2021-2030 | 15% |

### 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% |

### 3. IEA Reference Scenario

The *IEA Reference Scenario* is based on the projections for PV capacity in the International Energy Agency's latest World Energy Outlook (WEO 2006). WEO 2006 records actual market statistics up to 2004 and then builds its scenario on those figures. Solar Generation updates the IEA assessment with actual market statistics to 2006 and then uses the IEA assumptions to project those forward. In the *IEA Reference Scenario* conventional electricity sources remain dominant for the foreseeable future. **This scenario can therefore be regarded as a way for policy makers to see what an unsustainable energy future would look like compared with Solar Generation's Advanced Scenario.**

| Market growth rates under the *IEA Reference Scenario* | |
|---|---|
| Average growth rate 2007-2010 | 16% |
| Average growth rate 2011-2020 | 13% |
| Average growth rate 2021-2030 | 10% |

The growth rates presented in all 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 2006). These show global demand for power increasing from 14,374 TWh in 2004 to 17,467 TWh in 2010, 22,775 TWh in 2020, 28,098 TWh in 2030 and 31,951 TWh in 2040 (extrapolated).

The *'Alternative Scenario'* for future electricity demand is based on the Greenpeace/European Renewable Energy Council Energy Revolution 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, 19,189 TWh in 2030 and 22,516 TWh in 2040. 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 | | |
|---|---|---|---|---|
| | 2006 | 2010 | 2020 | 2030 |
| **Advanced Scenario** | | | | |
| Annual installations in GW | 1,5 | 5.6 | 44 | 179 |
| Cumulative capacity in GW | 6,6 | 28.9 | 241 | 1,272 |
| Electricity production in TWh | 8 | 25 | 320 | 1,802 |
| PV contribution to electricity consumption - reference scenario (IEA) | 0.05% | 0.14% | 1.83% | 6.41% |
| PV contribution to electricity consumption - alternative scenario | 0.05% | 0.18% | 1.93% | 9.39% |
| Grid connected people people in millions | 5 | 15 | 157 | 776 |
| Off grid connected people in millions | 10 | 61 | 966 | 2,894 |
| Employment in thousands | 74 | 271 | 1,840 | 6,329 |
| Market value in billion € | 9 | 25 | 113 | 318 |
| Annual $CO_2$ savings in million tonnes | 5 | 15 | 192 | 1,081 |
| Cumulative $CO_2$ savings in million tonnes | 20 | 61 | 898 | 6,671 |
| **Moderate Scenario** | | | | |
| Annual installations in GW | 1,5 | 4,2 | 28 | 84 |
| Cumulative capacity in GW | 6,6 | 18,4 | 170 | 728 |
| Electricity production in TWh | 8 | 21 | 225 | 1,027 |
| PV contribution to electricity consumption - reference scenario (IEA) | 0.05% | 0.12% | 0.99% | 3.66% |
| PV contribution to electricity consumption - alternative scenario | 0.05% | 0.15% | 1.36% | 5.35% |
| Grid connected people in millions | 5 | 13 | 111 | 450 |
| Off grid connected people in millions | 10 | 50 | 669 | 1,613 |
| Employment in thousands | 74 | 201 | 1,165 | 2,963 |
| Market value in billion € | 9 | 20 | 79 | 172 |
| Annual $CO_2$ savings in millions tonnes | 5 | 13 | 135 | 616 |
| Cumulative carbon savings in million tonnes | 20 | 56 | 680 | 4,252 |
| **IEA Reference Scenario** | | | | |
| Annual installations in GW | 1.5 | 1.4 | 3 | 8 |
| Cumulative capacity in GW | 499.3 | 9.9 | 33 | 87 |
| Electricity production in TWh | 8 | 12 | 50 | 142 |
| PV contribution to electricity consumption - reference scenario (IEA) | 0.05% | 0.07% | 0.22% | 0.50% |
| PV contribution to electricity consumption - alternative scenario | 0.05% | 0.08% | 0.30% | 0.74% |
| Grid connected people in millions | 5 | 8 | 24 | 58 |
| Off grid connected people in millions | 10 | 27 | 113 | 176 |
| Employment in thousands | 74 | 67 | 127 | 287 |
| Market value in billion € | 9 | 6 | 11 | 23 |
| Annual $CO_2$ savings in million tonnes | 5 | 6 | 27 | 77 |
| Cumulative carbon savings in million tonnes | 20 | 39 | 203 | 705 |

| **Projection to 2040 under Advanced Scenario** | |
|---|---|
| PV contribution to global electricity demand (IEA electricity scenario) | 20% |
| PV contribution to global electricity demand (alternative scenario – high energy efficiency) | 28% |

| Table 3.2: Solar Generation scenario PV market development (annual installed capacity) up to 2010 | | | | | |
|---|---|---|---|---|---|
| | 2006 | 2007 | 2008 | 2009 | 2010 |
| Advanced Scenario | 1,467 MWp | 2,179 MWp | 3,130 MWp | 4,340 MWp | 5,650 MWp |
| Moderate Scenario | 1,467 MWp | 1,907 MWp | 2,479 MWp | 3,223 MWp | 4,189 MWp |
| IEA Scenario | 1,467 MWp* | 888 MWp | 1,035 MWp | 1,204 MWp | 1,401 MWp |

*For 2006 the actual EPIA market figure is given. For later years the figures are based on extrapolation of IEA data.

***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 1,800 terawatt hours of electricity around the world. **This means that enough solar power would be produced globally in just over twenty years' time to satisfy the current electricity needs of 60% of the countries in OECD Europe.**

Under this scenario the global installed capacity of solar power systems would reach 1,272 GWp by 2030. About 60% 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 776 million. In Europe alone there would be roughly 220 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 290 GWp 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 2.9 billion people in the developing countries would by then be using solar electricity.** This would represent a major breakthrough for the technology from its present emerging status.

By 2040, the penetration of solar generation would be even deeper. Assuming that overall global power consumption had by then increased as expected, **the solar contribution would equal 20 - 28% of the world's electricity output, depending on which scenario is used for electricity consumption.** This would place solar power firmly on the map as an established energy source.

*PV module production line*

**Figure 3.1: Global PV cumulative capacity up to 2030**

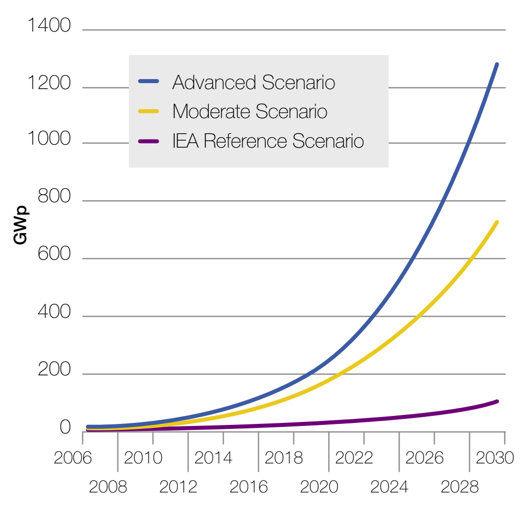



**Figure 3.2: Global PV annual installed capacity up to 2030**

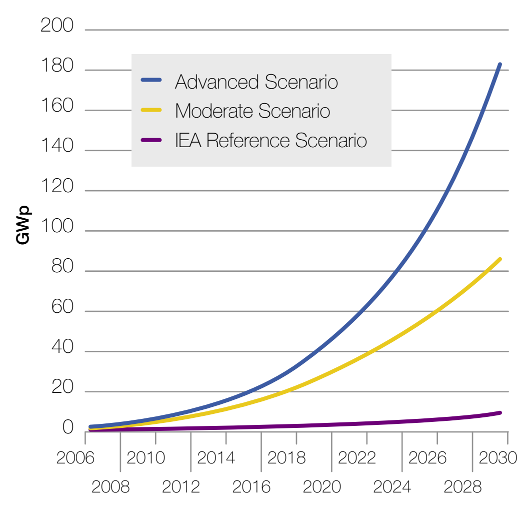



*Figure 3.1* illustrates the development of cumulative installed PV capacity under the three different scenarios. At the end of the scenario period, in 2030, the outcomes differ considerably. The most favourable outcome is under the Advanced Scenario, which is based on the positive growth of PV up to 2015, highlighting the importance of political commitment in the coming years. Adequate support for PV during this period (see *Part Six: Policy Drivers*) will therefore facilitate the achievement of the Advanced Scenario. In particular, the early development of the dynamic relationship between mass production and cost reduction is vital for establishing PV as a globally important energy source. *Figure 3.2* shows the development path for annual PV installations under the three scenarios.

*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 (MWp). However, the currently very dominant grid connected sector, representing roughly 85% of the market, will lose 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**

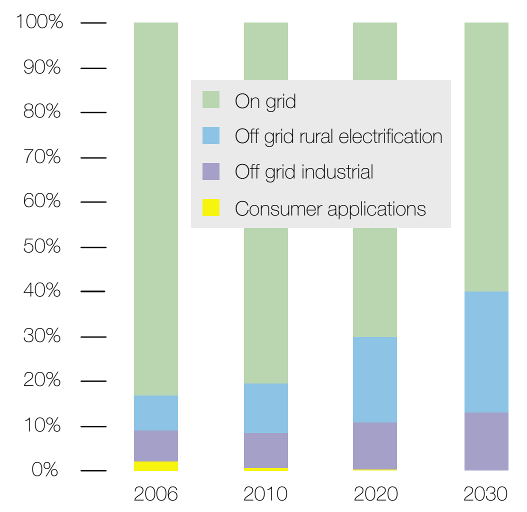


**Figure 3.4: Annual PV installations by regional share**

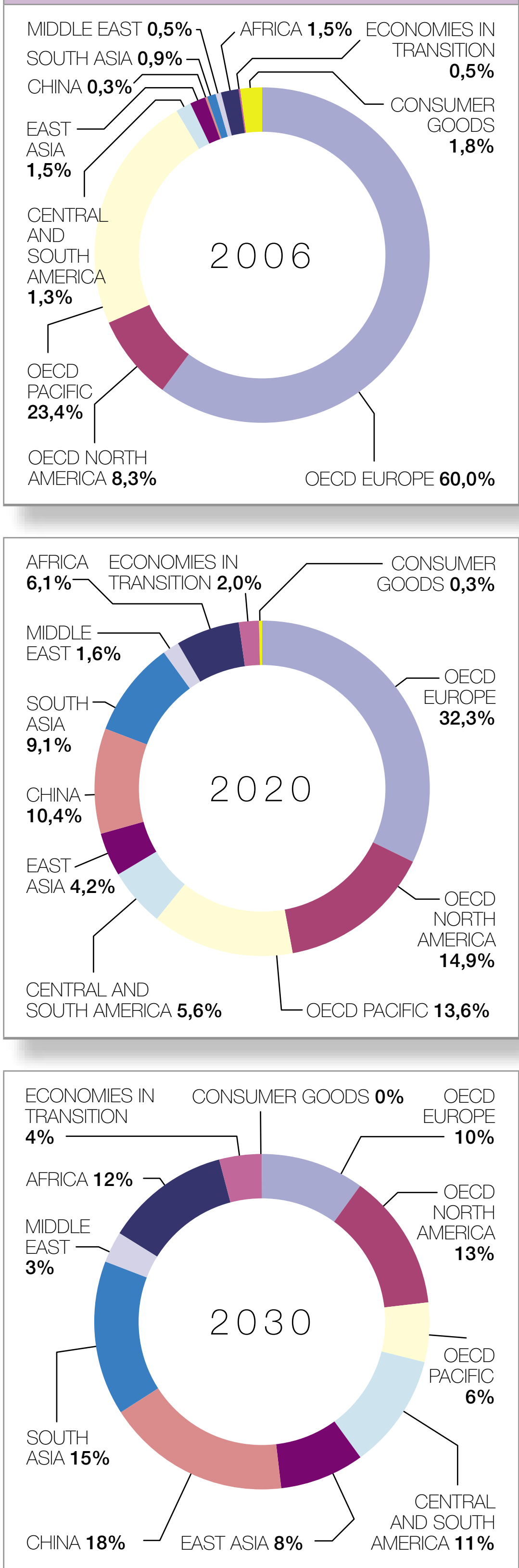
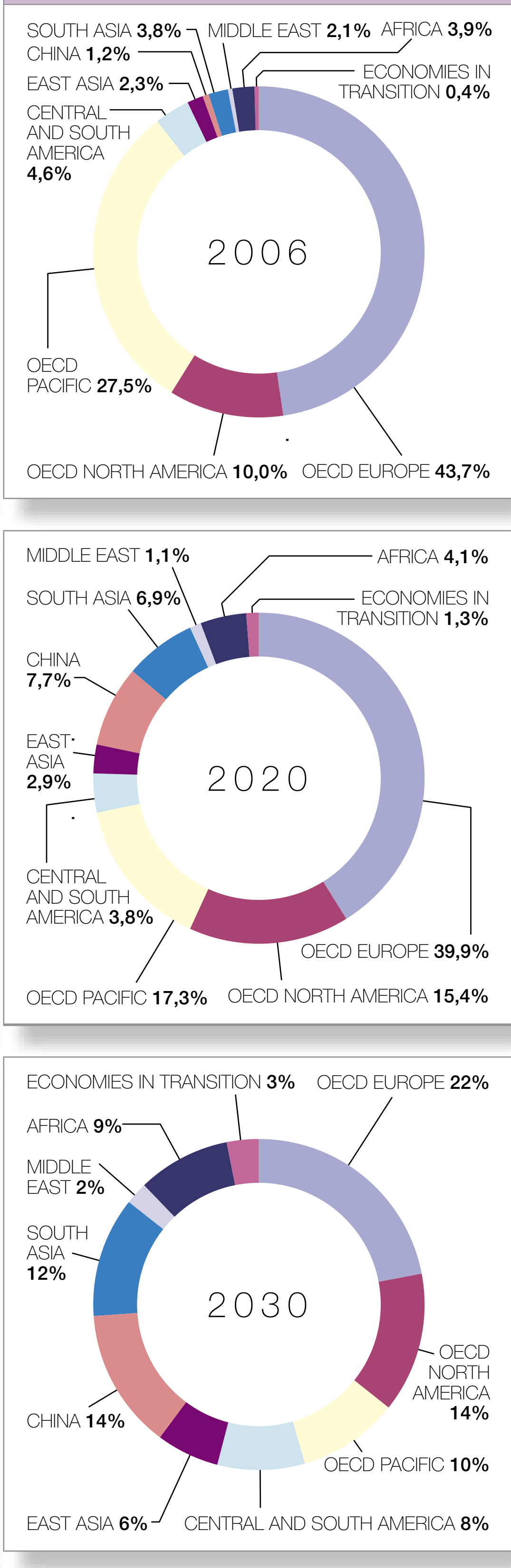



**Figure 3.5: Cumulative PV installations by regional share**



| Year | Europe | North America | OECD Pacific | Central and South America | East Asia | China | South Asia | Middle East | Africa | Transition Economies | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 5,129 | 900 | 1,962 | 126 | 138 | 72 | 84 | 48 | 138 | 48 | 8,645 |
| 2010 | 13,467 | 4,125 | 5,088 | 186 | 204 | 899 | 917 | 71 | 204 | 71 | 25,231 |
| 2015 | 25,134 | 9,199 | 10,112 | 1,654 | 1,318 | 3,857 | 3,521 | 485 | 1,806 | 607 | 57,694 |
| 2020 | 36,662 | 16,957 | 15,499 | 6,331 | 4,755 | 11,865 | 10,289 | 1,771 | 6,909 | 2,309 | 113,347 |
| 2025 | 39,643 | 26,192 | 18,422 | 15,546 | 11,430 | 26,680 | 22,564 | 4,276 | 16,960 | 5,659 | 187,372 |
| 2030 | 31,784 | 41,319 | 19,070 | 34,962 | 25,427 | 57,211 | 47,676 | 9,535 | 38,141 | 12,714 | 317,840 |

**Table 3.3: Market value of PV systems (annually) up to 2030 under the *Advanced Scenario* (in million €)**

Excluding consumer goods

**Table 3.4: Investment in new production capacities under the *Advanced Scenario* (in million €)**

| | 2007 | 2008 | 2009 | 2010 | Total |
|---|---|---|---|---|---|
| **Silicon** | 762 | 1,114 | 1,185 | 1,144 | 4,205 |
| **Wafers** | 667 | 807 | 765 | 901 | 3,140 |
| **Cells** | 381 | 461 | 437 | 515 | 1,794 |
| **Modules** | 381 | 461 | 437 | 515 | 1,794 |
| **Thin Film** | 473 | 719 | 1,089 | 644 | 2,924 |
| **Total** | 2,663 | 3563 | 3,913 | 3,718 | 13,857 |

*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.

*Tables 3.3* and *3.5* 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 318 billion Euros worldwide under the Advanced Scenario and 172 billion Euros under the *Moderate Scenario*.

*Large PV Power Plant with Thin Film Solar Modules*

**Table 3.5: Market value of PV systems (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 | Transition Economies | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 5,129 | 900 | 1,962 | 126 | 138 | 72 | 84 | 48 | 138 | 48 | 8,645 |
| 2010 | 10,492 | 3,214 | 3,962 | 145 | 159 | 700 | 714 | 55 | 159 | 55 | 19,656 |
| 2015 | 19,656 | 7,194 | 7,908 | 1,294 | 1,031 | 3,017 | 2,754 | 379 | 1,413 | 475 | 45,119 |
| 2020 | 25,533 | 11,810 | 10,794 | 4,409 | 3,312 | 8,263 | 7,165 | 973 | 4,812 | 1,608 | 78,679 |
| 2025 | 26,012 | 17,187 | 12,088 | 10,201 | 7,500 | 17,506 | 14,806 | 2,368 | 11,129 | 3,713 | 122,510 |
| 2030 | 17,215 | 22,380 | 10,329 | 18,937 | 13,772 | 30,987 | 25,823 | 5,165 | 20,658 | 6,886 | 172,151 |

Excluding consumer goods

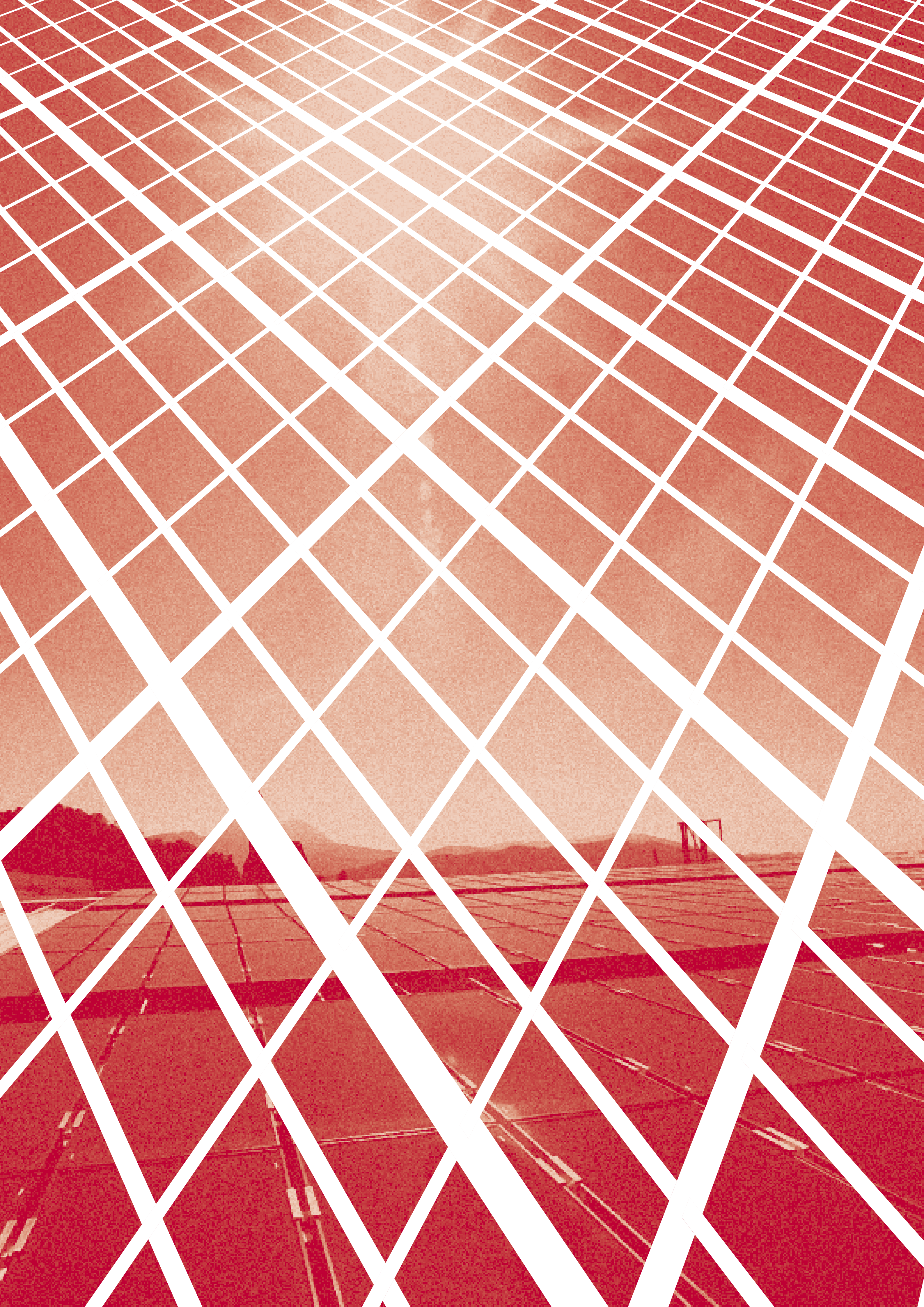
**Table 3.6: Investment in new production capacities under the *Moderate Scenario* (in million €)**

| | 2007 | 2008 | 2009 | 2010 | Total |
|---|---|---|---|---|---|
| **Silicon** | 440 | 693 | 874 | 1117 | 3,125 |
| **Wafers** | 385 | 482 | 564 | 880 | 2,311 |
| **Cells** | 220 | 275 | 322 | 503 | 1,320 |
| **Modules** | 220 | 275 | 322 | 503 | 1,320 |
| **Thin Film** | 329 | 483 | 806 | 628 | 2,246 |
| **Total** | 1,595 | 2,208 | 2,889 | 3,631 | 10,323 |

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 3.4* 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 nearly 14 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*



# 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*


## 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 life cycle 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 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 EU 27 countries, however, with 2006 residential prices ranging, according to Eurostat, between 7 and 24 €cents/kWh (including all taxes). The most recent trend has also been a steady increase. From 2005 – 2007 electricity prices in the EU-27 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 | 2006 | 2010 | 2020 | 2030 |
|---|---|---|---|---|---|
| Berlin | 900 | 0.45 € | 0.35 € | 0.20 € | 0.13 € |
| Paris | 1,000 | 0.40 € | 0.31 € | 0.18 € | 0.12 € |
| Washington | 1,200 | 0.34 € | 0.26 € | 0.15 € | 0.10 € |
| Hong Kong | 1,300 | 0.31 € | 0.24 € | 0.14 € | 0.09 € |
| Sydney/Buenos Aires/ Bombay/Madrid | 1,400 | 0.29 € | 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 € |

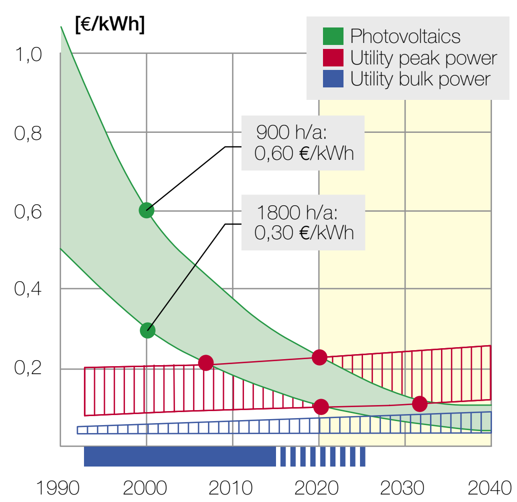
Note: The calculation method has been changed from the previous edition of 'Solar Generation'.

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 taken 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.

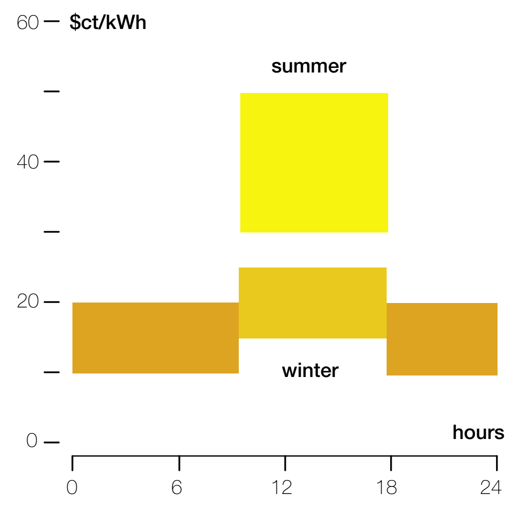
*Figure 4.1* shows the historical and expected future development of solar electricity costs. The falling curves show the reduction in costs in the geographical area between central Europe, for example Northern Germany (upper curve), and the very south of Europe (lower curve). In contrast to the falling 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**




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

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 4.2* 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.

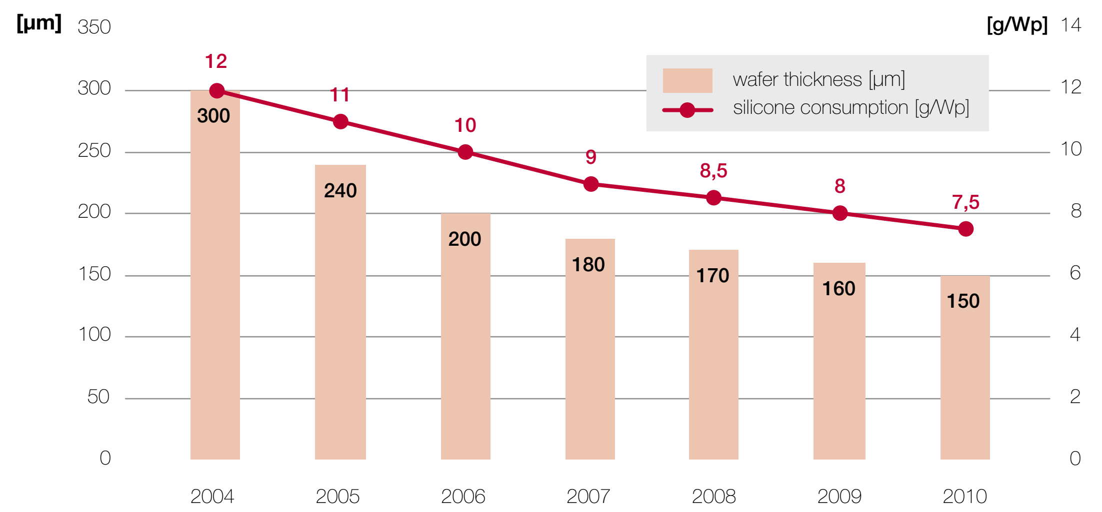
## External costs of conventional electricity generation

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 thicknes**




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**

Those 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 that 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***

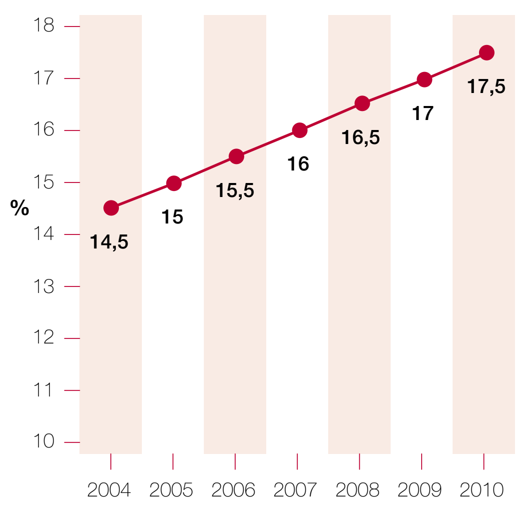
Thin film efficiencies to reach between 10% and 12% (for a-Si/mc-Si, CIS and CdTe) by 2010 and then 15% by 2020

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 m2 by 2010 and to 9 m2 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*



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, 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 MWp, today's market leaders have 1 GWp 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 the 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 rapidly introduce innovative policies 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, therefore - 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*



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. This can offset investment in major new plant and 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** | | | | | | |
| 2006 | 48,017 | 14,375 | 4,312 | 1,869 | 5,390 | 73,963 |
| 2010 | 178,915 | 50,828 | 15,248 | 6,608 | 19,060 | 270,659 |
| 2015 | 530,620 | 139,821 | 41,946 | 18,177 | 52,433 | 782,997 |
| 2025 | 2,462,198 | 532,943 | 159,883 | 69,283 | 199,854 | 3,424,161 |
| 2030 | 4,716,534 | 893,283 | 267,985 | 116,127 | 334,981 | 6,328,909 |
| **Moderate Scenario** | | | | | | |
| 2006 | 48,017 | 14,375 | 4,312 | 1,869 | 5,390 | 73,963 |
| 2010 | 132,718 | 37,704 | 11,311 | 4,902 | 14,139 | 200,774 |
| 2015 | 387,526 | 102,115 | 30,634 | 13,275 | 38,293 | 571,843 |
| 2020 | 811,805 | 195,683 | 58,705 | 25,439 | 73,381 | 1,165,012 |
| 2025 | 1,439,671 | 311,617 | 93,485 | 40,510 | 116,856 | 2,002,140 |
| 2030 | 2,208,195 | 418,219 | 125,466 | 54,368 | 156,832 | 2,963,080 |
| **IEA Reference Scenario** | | | | | | |
| 2006* | 48,017 | 14,375 | 4,312 | 1,869 | 5,390 | 73,963 |
| 2010 | 44,407 | 12,616 | 3,785 | 1,640 | 4,731 | 67,179 |
| 2015 | 52,713 | 13,890 | 4,167 | 1,806 | 5,209 | 77,784 |
| 2020 | 88,545 | 21,344 | 6,403 | 2,775 | 8,004 | 127,071 |
| 2025 | 137,988 | 29,867 | 8,960 | 3,883 | 11,200 | 191,898 |
| 2030 | 213,791 | 40,491 | 12,147 | 5,264 | 15,184 | 286,877 |

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

In 2006 the German PV industry alone employed 35,000 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 6.3 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, the

*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* (GW EC).

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

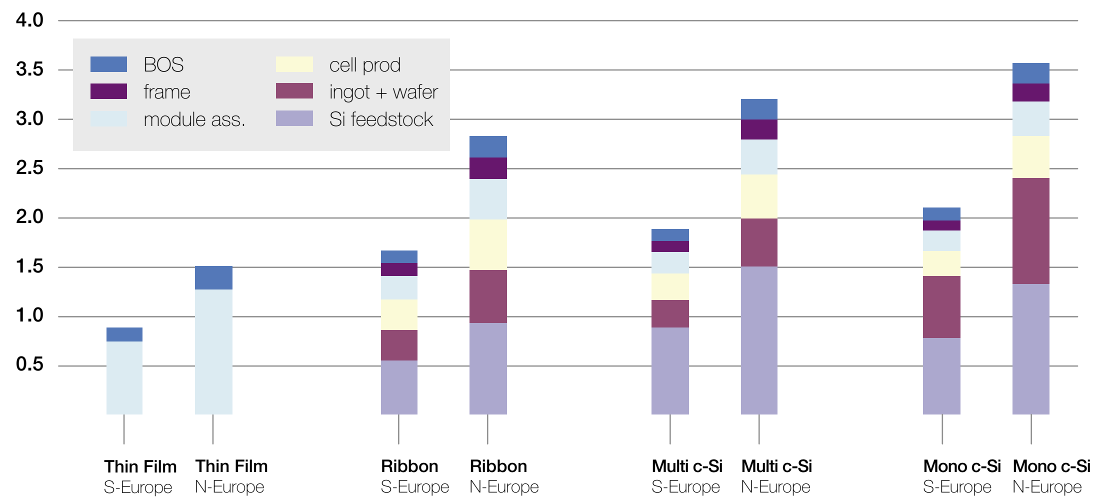
Solar power can be easily installed in remote and rural areas, places that may not be targeted for grid connection for many years. Renewable energy sources such as PV are currently one of the few suitable options to supply electricity in areas of dispersed communities or at a large distance from the 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, thus increasing economic productivity and creating 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.

**Figure 5.1: Energy payback times for range of PV systems**




Source: Alsema, De Wild, Fthenakis, 21st European Photovoltaic Energy Conference, Dresden 2006

During 2005, 86 MWp of PV solar energy was installed in rural areas in developing countries, enabling access to electricity for approximately 800,000 families.

## 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, multicristalline and monocristalline) 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 monocristalline 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 life-cycle, 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, therefore, 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, 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, so higher $CO_2$ savings may well be possible.

*Building HLM in Echirolles, France*


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 billion tonnes. This reduction is equivalent to the 2004 emissions from the whole of India, or the output from 300 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 6.6 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 | | Iea Reference Scenario | |
|---|---|---|---|---|---|---|
| | **Annual $CO_2$ savings in million tonnes** | **Cumulative $CO_2$ savings in mt** | **Annual $CO_2$ savings in mt** | **Cumulative $CO_2$ savings in mt** | **Annual $CO_2$ savings in mt** | **Cumulative $CO_2$ savings in mt** |
| **2006** | 5 | 20 | 5 | 20 | 5* | 20* |
| **2007** | 6 | 26 | 6 | 26 | 3 | 24 |
| **2008** | 8 | 35 | 8 | 34 | 4 | 28 |
| **2009** | 11 | 46 | 10 | 44 | 5 | 33 |
| **2010** | 15 | 61 | 13 | 56 | 6 | 39 |
| **2011** | 20 | 80 | 16 | 72 | 7 | 46 |
| **2012** | 27 | 108 | 22 | 95 | 8 | 54 |
| **2013** | 35 | 143 | 29 | 123 | 10 | 64 |
| **2014** | 46 | 189 | 37 | 160 | 12 | 76 |
| **2015** | 59 | 248 | 46 | 206 | 14 | 91 |
| **2016** | 76 | 324 | 58 | 264 | 18 | 109 |
| **2017** | 101 | 424 | 76 | 339 | 20 | 129 |
| **2018** | 126 | 550 | 93 | 432 | 22 | 151 |
| **2019** | 156 | 706 | 112 | 544 | 25 | 176 |
| **2020** | 192 | 898 | 135 | 680 | 27 | 203 |
| **2021** | 234 | 1,132 | 162 | 841 | 30 | 233 |
| **2022** | 282 | 1,414 | 192 | 1,034 | 33 | 267 |
| **2023** | 338 | 1,753 | 227 | 1,261 | 37 | 304 |
| **2024** | 403 | 2,156 | 266 | 1,527 | 41 | 345 |
| **2025** | 478 | 2,634 | 310 | 1,838 | 46 | 391 |
| **2026** | 570 | 3,205 | 362 | 2,200 | 51 | 441 |
| **2027** | 672 | 3,876 | 417 | 2,617 | 56 | 497 |
| **2028** | 789 | 4,665 | 477 | 3,093 | 62 | 560 |
| **2029** | 924 | 5,589 | 543 | 3,636 | 69 | 629 |
| **2030** | 1,081 | 6,671 | 616 | 4,252 | 77 | 705 |

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

*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, 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) and 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 4.0 °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, at least as long as the Bush administration is in power. The only other Annex B country to have announced it will not ratify is 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 as well as generating 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 1,500 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 300 coal-fired power plants (average size 750 MW).

Global installed capacity of solar power systems could reach 1,300 GWp by 2030. About two thirds 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 776 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 2.9 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. That right cannot be taken for granted, therefore, and will need to be argued for against 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?*

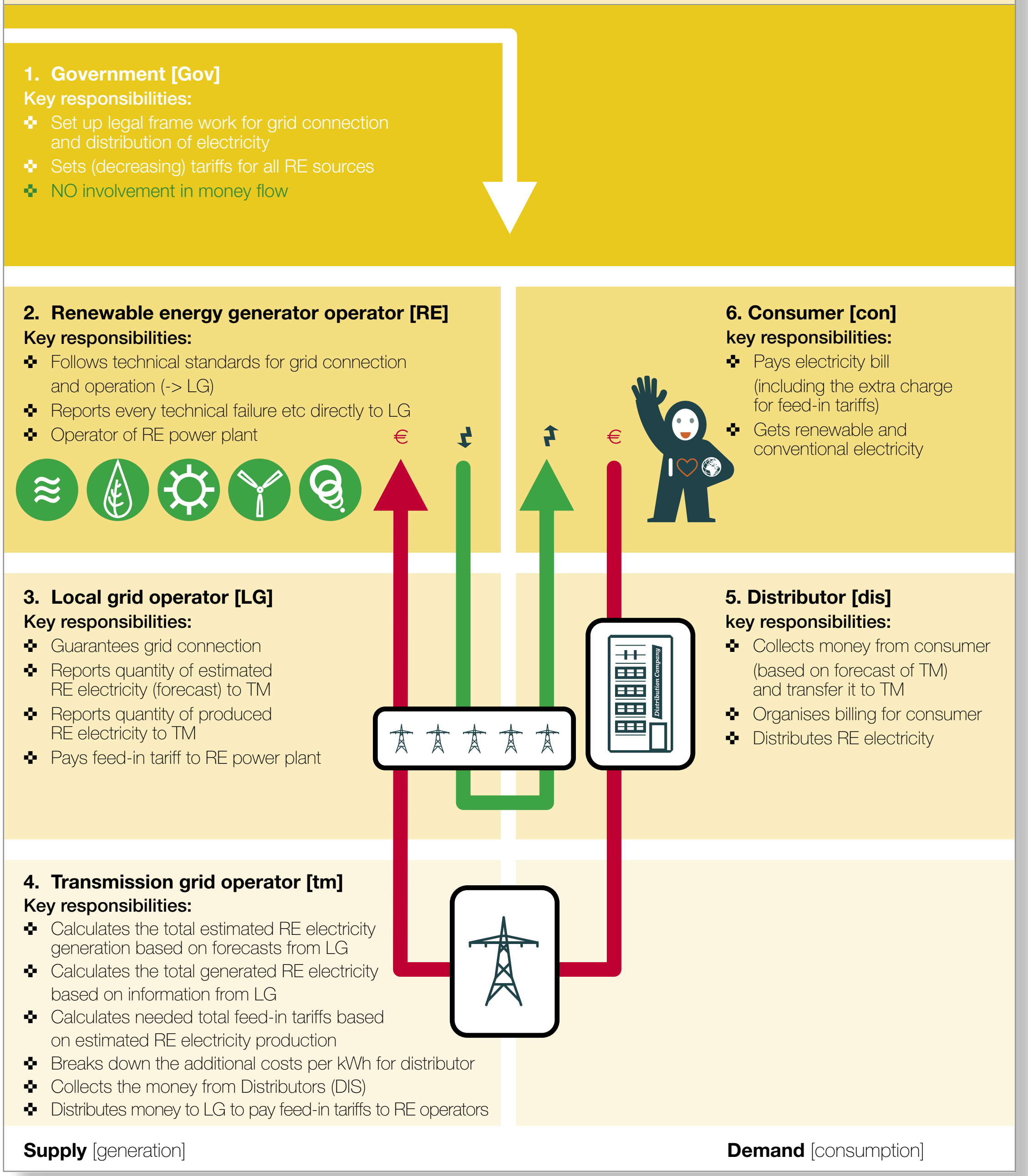
In the past, in order to encourage solar electricity, many programmes were financed through government budgets. The disadvantage of this method has been that if the state money ran out, or was curtailed, the programme could be stopped. Therefore some feed-in tariff models take a completely different approach. In Germany in 2007 the utilities pay a premium tariff of between €0.38/kWh and €0.54/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 consumer due to the premium tariff for solar electricity are currently €0.20. 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 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%, 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.

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




***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.

### 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 them-selves 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 its interest in renewables in order to make sure that the necessary financing is in place to keep up the current rate of expansion.

#### *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

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, offering 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.

## International policy on PV solar power

### Current policy in the European Union

The most important European support measure for PV is *Directive 2001/77/EC* on the promotion of electricity produced from renewable energy sources, known as the Renewable Electricity Directive. This set a target to double the share of renewable energy from 6% to 12% of gross energy consumption in Europe by 2010 and to increase the proportion of renewable electricity to 22%.

In order to reach these goals the Directive has set indicative targets for each EU Member State, requiring them to produce National Action Plans and set their own targets for renewable electricity. To achieve this they have been allowed to established support schemes for the promotion of renewable energy sources. Furthermore, they have been required to **eliminate administrative barriers** in relation to authorisation procedures, to grant **fair access to the grid** to renewable electricity and to ensure **guarantees of origins** for renewable electricity.

### Proposed legislation on renewable energy

In January 2007 the European Commission issued a Communication on a Renewable Energy Road Map as part of a comprehensive Energy Package. This Communication aims to further promote the development of renewable energy sources in Europe by setting a target for a 20% share of renewables in the EU's energy mix by 2020. The proposed legislation will set legally binding targets for renewable energy in each Member State, which will then be required to establish National Action Plans outlining their specific objectives for each of the renewable energy sectors (fuel, electricity and heating/cooling).

Full details of the proposed Directive have not yet been agreed, in particular whether it will require Member States to set sectoral targets for electricity, heating/cooling and bio–fuels. This would be particularly important for the promotion of renewable energy sources since it would create a secure and stable framework for investment. Nonetheless, the new Directive is expected to improve the existing provisions of the Renewable Electricity Directive, and not weaken it.

A debate is also continuing in the European Union about the possible harmonisation of support schemes for renewable electricity. EPIA believes that such a harmonisation would hinder rather than foster the development of renewable sources of electricity.

Finally, PV could be positively affected by forthcoming legislation (announced in the Communication on the *Prospects for the internal gas and electricity market* COM (2006) 841) on the liberalisation of the internal electricity market. More effective measures to 'unbundle' ownership of the distribution and transmission systems from the large power utilities would open up new market opportunities for the PV industry.

### Current policy in the United States

***Solar Power Manufacturing***

Over the past two years PV manufacturing facilities have diversified and expanded greatly, providing a silver lining to the shortage in silicon. The best example of this diversification is the expansion of thin film solar cells. The US leads the world in thin film production, with nearly half the global output. Venture capital is also flooding into the solar industry, especially to third-generation and nanotechnologies.

***Federal Tax Credit***

Strong support exists within Congress for a long-term extension of the Solar Tax Credit, which was first introduced in 2005. The credit provides a tax incentive for investors in PV systems, much as a similar credit has encouraged a booming US wind power industry. Legislation already introduced in the House and Senate would extend the tax credit for eight years and remove the cap (upper limit) for residential buildings. The prospects for an early extension of the tax credit are strong.

### *The President's Solar America Initiative*

The Department of Energy has released details of the „President's Solar America Initiative," proposing a large funding increase for solar energy research. This initiative aims to make solar competitive with existing sources of electricity by 2015. The programme also aims to deploy 5 - 10 GWp of capacity, which is in line with the growth projected by industry and promoted by state incentives, by the same target date. By 2030 up to 70 – 100 GWp of capacity could be installed, roughly the same as the current electricity generation of New York and California combined. 40 % of new electricity generation capacity would be from PV by 2030.

As a result of the Initiative and the popularity of solar power within Congress, the federal budget for solar research and development has grown significantly over the past two years. The Initiative will place emphasis on funding industry-led partnerships to accelerate market-ready photovoltaics with a new focus on manufacturing and production.

### *State Policies*

In the last couple of years a handful of states have passed laws promoting the large-scale adoption of solar power. Lead by California, New Jersey, Arizona, Pennsylvania and now Maryland, the states have currently committed to fund the installation of over 10 GWp of solar electricity in the next 15 years. These programmes will deliver billions of dollars in subsidies to residential and commercial solar projects and represent significant long-term incentives to the solar industry in the United States.

In San Fransisco (California), the local authority has recently chosen to establish its own energy supply company, Community Choice Energy. The city plans to create one of the world's largest urban solar facilities and install a total of 360 MW of renewable energy, enough to power over half of the urban area's needs by 2017.

**Summary of State Solar Goals (MWp)**

| State | Commitment by 2020 |
|---:|---:|
| Arizona | 2,000 |
| California | 3,000 |
| Connecticut | 15 |
| Colorado | 200 |
| Deleware | 175 |
| District of Columbia | 30 |
| Hawaii | 15 |
| Maryland | 1,400 |
| Nevada | 500 |
| New Hampshire | 34 |
| New Jersey | 1,500 |
| New York | 25 |
| North Carolina | 240 |
| Pennsylvania | 860 |
| Texas (Austin) | 100 |
| Other States* | 300 |
| **Total** | **10,394** |

## Current policy in Japan

The encouragement of solar PV in Japan has come through a range of legal measures, national strategies and frameworks implemented by the Ministry of Economy, Trade and Industry (METI) and other government ministries and agencies. Japan's target for the cumulative capacity of PV systems to be installed by 2010 is 4,820 MW. METI has been actively driving forward measures for PV deployment and R&D programmes to achieve this target.

The New Energy Law of 1997 defined the responsibility of each sector - national and local government, energy consumers, energy suppliers and energy system manufacturers - to introduce and expand new and renewable energy sources. Under the Renewables Portfolio Standard (RPS) law of 2002, energy suppliers are obliged to purchase an increasing percentage of renewable energy each year. In addition, the Japanese government introduced a Basic Energy Plan in 2003 in order to support these policies.

In 2004, three projections for Japanese energy supply up to the year 2030 were released, including a PV Roadmap to 2030 (PV2030). This outlined the technological development of PV systems required to achieve larger scale dissemination in the longer term. In 2005, the government endorsed the Kyoto Protocol Target Achievement Plan, which again emphasised the large-scale deployment of new and renewable energy as one of the countermeasures to reduce greenhouse gas emissions up to 2010.

In 2006, METI announced the New National Energy Strategy, in which the promotion of PV systems is established as one of the major pillars. Two other recent laws on promoting measures to cope with global warming and the promotion of green purchasing have also been introduced to promote new and renewable energy.

## Current policy in China

The most important development for renewable energy in China, including solar PV, was the introduction at the beginning of 2006 of the Renewable Energy Law. Among its main provisions are:

- Power companies must enter into grid connection agreements with renewable power generation enterprises that have legally obtained an administrative license, and purchase their output.
- The price for electricity from renewable energy power projects is determined by the State Council according to the principle of being "beneficial to the development and utilisation of renewable energy and being economic and reasonable", with adjustments on the basis of the future development of the technology.
- The price paid for renewable power should reflect the difference between its current cost and that of "conventional" energy sources.
- The government will support the construction of independent renewable power systems in areas not covered by the power grid to provide a service for local industry and households.

The National Development and Reform Commission (NDRC), which has overall responsibility for energy policy in China, made a further announcement about the price to be paid for PV electricity under the Renewable Energy Law. This determined that the price level laid down by the State Council would be based on the principle of "reasonable costs plus reasonable profits", and that any additional costs incurred by PV generators, including operations and maintenance and grid connection charges, would be settled by a tariff surcharge levied on electricity consumers. Both building-integrated PV systems and large-scale desert PV power plants will be subject to this "feed-in tariff" policy.

For off-grid central PV power plants in villages, the initial investment will be paid by the government (household systems are not included) and the portion of the cost of operation and maintenance that exceeds the revenue from electricity fees (including the cost of renewing the storage batteries) will be apportioned to the nationwide electricity network by increasing the electricity tariff.

However, another important point is made in the legislation. End-users (whether grid-connected or off-grid) are expected to pay for their electricity according to the "same network, same price" principle; that is to say, the electricity tariff paid by PV power users should be the same as the electricity tariff paid by grid-connected power users in the same area.

### *Practical problems*

#### Grid-connected systems

Many PV power systems capable of being connected to the grid have been built in China, with capacities ranging from several kWp to 1 MWp, but in no case has a feed-in tariff, calculated according to "reasonable costs plus reasonable profits", been implemented and no system has as yet been permitted by the power companies to connect to the grid as a commercial venture. This is very different from the situation with wind energy. Wind farms have been built profitably by developers for many years (without needing capital investment from the state), and power companies have accepted these and accordingly executed the "feed-in tariff" policy.

To encourage electricity companies to accept PV output unequivocally, and purchase the power for a fair feed-in tariff price, the following changes are needed:

- Reasonable feed-in tariff prices should be established (for off-grid plants, the reasonable cost of operation and maintenance needs to be estimated).
- Standards for construction and testing, as well as market access rules, need to be established.
- Electricity companies should accept PV power and purchase it at a reasonable feed-in tariff price.
- The additional cost of generation needs to be spread across the national electric network.

#### Off-grid systems

Problems have also occurred over payments under the Renewable Energy Law for more than 720 PV plants installed under the Township Electrification Program. A mechanism needs to be urgently developed to incorporate the renewable electricity tariff into the nationwide electricity network so the accumulated funds can be used for the later-stage operation and maintenance of these rural PV plants. Otherwise, their investment value of several thousand million Yuan will be wasted. Unless action is taken a similar crisis is likely to face the Power Transmission to Village Program, which is about to be implemented.

What this experience shows is that it is not enough to introduce a Renewable Energy Law without considering the implementation of its details, especially the correct level of feed-in tariff and cost sharing.

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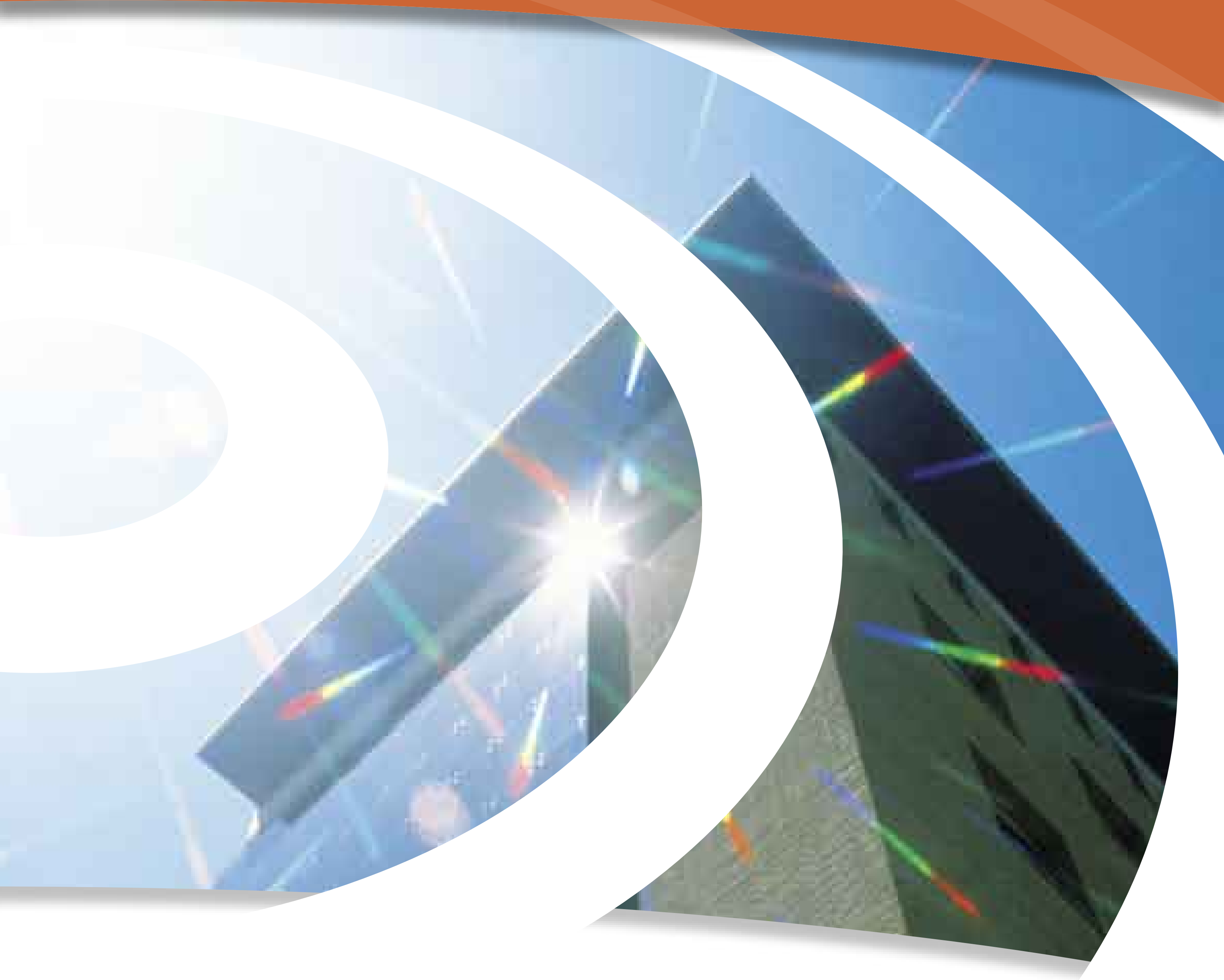

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