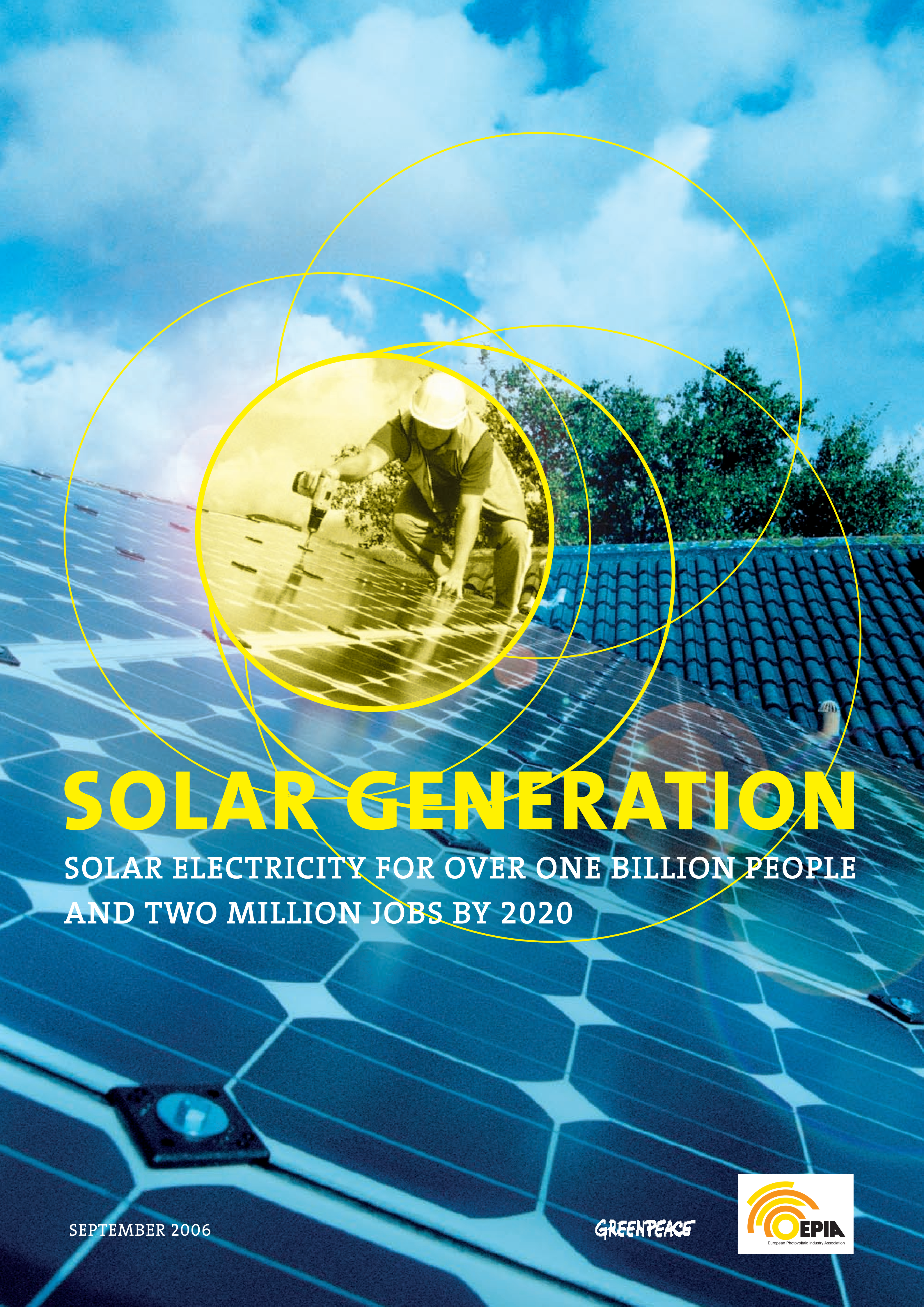

SOLAR GENERATION

SOLAR ELECTRICITY FOR OVER ONE BILLION PEOPLE AND TWO MILLION JOBS BY 2020

SEPTEMBER 2006

GREENPEACE

EPIA
European Photovoltaic Industry Association

CONTENTS

Note: The currency quoted in this report is mainly the US dollar, with the euro in some sections on European countries.

FOREWORD

The Solar Generation project, conceived in 2000 by Greenpeace and the European Photovoltaic Industry Association (EPIA), is entering its next phase, and addresses major challenges facing the global society:

1. Employment and solar industry
2. Security of affordable energy supplies
3. Poverty eradication
4. Climate change

It has become clear that energy access has become a priority if we are to enable sustainable and fair development for future generations.

EPIA and Greenpeace have published this third edition of Solar Generation to update our understanding of the contribution that solar power can make to the world's energy supply. The report is a practical blueprint showing that solar power is capable of supplying electricity to more than one billion people within two decades, even if overall electricity use doubles in that time.

Solar Generation aims to define the role that solar electricity will play in the lives of a population born today and growing up as an important energy saving and consumption group. We have examined how solar electricity will be perceived from both the consumer and the solar business perspective within the timescale of this single generation. The report highlights the worldwide benefits of solar energy - for the climate and environment, social development, the economy and supply chain as well as for industry and employment.

1. EMPLOYMENT AND SOLAR INDUSTRY

Solar photovoltaics (PV) can and should play an important role within a future sustainable energy system. PV is one of the key technologies for generating decentralised electricity for private households around the world, and the technology is currently maturing. The market has grown by more than 40% a year for almost a decade and the industry is investing large sums to increase production facilities.

The further development of PV solar electricity from a niche market to a mainstream technology will be crucial in 2006 and 2007. For the expansion of solar energy to be successful there must be a clear commitment from governments. The global photovoltaic industry has already made large investments and to ensure this investment continues into the future there must be a stable political framework to support it.

FOREWORD

Adequate market support programs in a relatively small number of countries has already led to the first market rush for PV energy. The German Feed In Tariff Act (EEG), for example, has created long-term conditions to help the PV solar electricity industry become a remarkable business partner with the potential for major job creation. This is about to continue when new investments in production facilities for solar silicon cells and modules are made between 2007 and 2010. The PV solar industry is at a crossroads – once the supply bottleneck is passed and new facilities are ready to allow for major growth in production the industry can then become a serious player in the power sector. Phasing-in PV solar electricity will therefore require a shift from centralised to decentralised power production, passing far greater control to individual consumers.

2. SECURITY OF AFFORDABLE ENERGY SUPPLY

As oil, gas and coal prices continue to rise with the supply often coming from politically unstable countries, the question of an affordable, clean and secure energy supply points to a need for renewable energies. More and more people see that fossil fuels have a negative impact on the world's climate, the economy and our everyday lives. Renewable energies and energy efficiency can cover future energy needs, but a long-term strategy is needed if this is to become reality. The shift in the energy sector will takes a least one generation – the 'Solar Generation'.

Security of energy supply – both through access to fuels and price stability – is an increasingly important part of the current global energy debate. If developing countries base their economic growth on the former model of industrialised countries, our planet will not be able to support this expansion in a sustainable way. The rapidly increasing demand for fossil fuels in 2006 propelled the price of crude oil above US$75 per barrel for the first time, showing that the price of oil will continue to rise sharply for supply to meet this growing demand. Economies unprepared for diversification of their energy mix will be particularly affected by these developments in the world oil market.

Solar power is a prime choice in developing an affordable and feasible global power source that can substitute fossil fuels in all the world's climate zones. The solar radiation reaching the earth's surface in one year provides more than 10,000 times the world's yearly energy needs. Whereas large solar thermal power plants can harvest the sun's power in dry and hot desert-like areas, PV solar electricity can provide decentralised energy supply at the very place it is consumed.

SolarGeneration III is a collaboration between EPIA, Greenpeace International and the German Aerospace Centre (DLR), the largest engineering research organisation in Germany. Projections on the future pattern of solar energy development have been extrapolated from a larger study of global sustainable energy pathways up to 2050 conducted by DLR for Greenpeace and the European Renewable Energy Council (EREC).

Renewable energies and in particular PV solar electricity have long-term potential. The benefits of solar power are compelling: environmental protection, economic growth, job creation, secure and distributed generation, diversity of fuel supply and rapid deployment, as well as the global potential for technology transfer and innovation. Most decisions on energy made today overlook solar power as a decentralised and modular technology, which can be rapidly deployed to generate electricity in developing areas.

3. POVERTY ERADICATION

Poverty eradication is a prerequisite for future peace. Some two billion people currently live with no access to energy services and this is set to rise if no action is taken. An essential part of tackling this is developing energy infrastructure, especially in rural areas of China, India, Africa and South America. PV solar energy already makes decentralised energy supply economical, which will become even more pronounced with future reductions in the cost of PV systems. We can envisage an increase from today's 10% market devoted to off-grid rural PV systems to 50% in the coming decades.

4. CLIMATE CHANGE

Climate change is increasingly accepted as one of the biggest man-made threats to the planet. We have now reached a point where CO_2 and other greenhouse gas emissions have already induced excessive floods, droughts and intensified hurricanes and typhoons. If we do not rigorously change our addiction to fossil fuels we will very soon cross a point when not only will more floods, droughts and heavier storms occur, but changes in ocean circulation and the melting of glaciers and artic ice will also produce destructive results for mankind.

Fortunately, we have technologies at hand – the portfolio of renewable energies – that could change this downward spiral and lead to a green and sustainable future.

CONCLUSION

Reports are a useful guide, but it is people's actions that really change things. We encourage politicians and policymakers, global citizens, energy officials, companies, investors and other interested parties to support solar power. By taking the crucial steps to help ensure that more than a billion people obtain electricity from the sun in the future we can harness the full potential of solar power for our common good.

September 2006

EPIA

DR. WINFRIED HOFFMANN
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Greenpeace

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EXECUTIVE SUMMARY

GLOBAL STATUS OF SOLAR PHOTOVOLTAICS

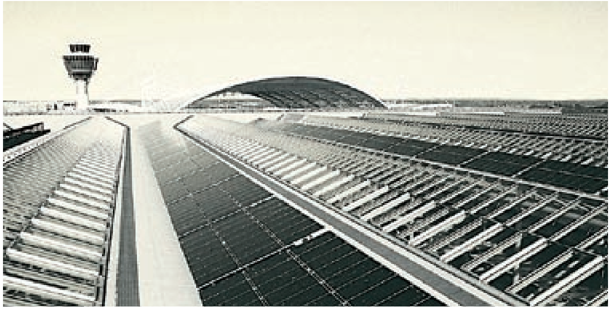
The solar electricity market is booming. In 2005 the cumulative installed capacity of solar photovoltaic (PV) systems around the world passed the landmark figure of 5000MWp. Global shipments of PV cells and modules have been growing at an average annual rate of more than 35% for the past few years.

Such has been the growth in the solar electricity industry that business only of the European PV industry in 2005 was worth more than €5 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 photovoltaic 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 promotion frameworks being put in place in a number of countries, notably Germany and Japan.

Since the first issue of Solar Generation was produced in 2001, the global market has continued to expand at the rate then predicted. While some countries, such as the United States, have lagged behind in their expected development, others such as Germany have exceeded expectations. There is also evidence of new enthusiasm for solar power in some of its most promising potential world markets, such as China.

This the third issue of our global solar PV market forecast Solar Generation after its first appearances in 2001 and in 2004. Since then, our estimates have been proved to be realistic, even a little conservative, as the market grew faster. Compared to the first market forecast, the market volume in 2005 was three years ahead of schedule, and the market volume in 2010 is now expected to be over 5500MW – twice our expectation in 2001.



This clear commercial commitment to the expansion of the PV industry means that the current surge of activity in the solar electricity sector represents only 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 while 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 ience 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 2025

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 can be made on the likely development of the solar electricity market up to 2025 and beyond. The results which have emerged from this extensive analysis point to a technology that is going to have a significant future impact on the everyday lives of the population born today.

Clearly, this transformation will not happen by itself. It will require the far-reaching commitment of consumers and industry, as well as significant political will. The level of commitment needed, however, has already been demonstrated in those countries which show the greatest growth in their solar electricity industries. We must learn from them and adapt and de-

Annual MW installation capacity: Market versus "SolarGeneration" scenario predictions since 2001

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Market Result MW]	334	439	594	815	1397					
SG I (2001) [MW]	321	408	518	659	838	1060	1340	1700	2150	2810
SG II (2004) [MW]					985	1283	1675	2190	2877	3634
SG III (2006) [MW]						1883	2540	3420	4630	5550

ploy the corresponding catalysts at a global level if solar electricity is to fulfil the potential that we need it to.

SOLAR GENERATION: METHODOLOGY AND ASSUMPTIONS

Taking its lead from Japanese and German success stories, 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 two 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 could be created, and the crucial effect that an increased input from solar electricity will have on greenhouse gas emissions.

This scenario for 2025, 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 used:
MARKET GROWTH RATES: The average annual growth rate of the worldwide PV market up to 2009 is projected to be 35% and 26% between 2010 and 2015. Between 2016 and 2025, the market will slowly consolidate at a high level, growth rates going down to 19% until 2020 and 11% between 2021 and 2025. Although initial growth is expected to be fastest in the grid-connected sector, by 2010 the off-grid sector will play an increasing role.

ELECTRICITY GENERATION: Figures for the growth in global electricity demand up to 2020 (on which comparisons with expected PV development are based) have been taken from projections by the International Energy Agency. These show total world power demand increasing to 23,000 Terawatt hours (TWh) by 2025. DLR has been asked by Greenpeace International and EREC to conduct a study on global sustainable energy pathways up to 2050. The scenarios are based on the reference scenario from IEA World Energy Outlook (2004). The energy demand is split up in electricity and fuels. A low energy demand scenario has been developed based on the IEA reference scenario: For the year 2025, the energy efficiency scenario estimates a global electricity demand of 16.845 TWh in 2025.

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.

PROJECTION TO 2040: For the period 2025-2040 a moderate annual growth rate of 15% has been assumed, as well as a very conservative lifetime of 20 years for PV modules.

The scenario is 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. These regions are OECD Europe, OECD Pacific, OECD North America, Latin America, East Asia, South Asia, China, the Middle East, Africa and the Rest of the World.

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. These key results are shown in *Table 1*.

Table 1: Key results of the EPIA/Greenpeace analysis

	2025	2020
Global Solar Electricity Output in 2025:	**589 TWh**	**276 TWh**
Global electricity demand in 2025 / 2020 (IEA projection)	2,5 %	1,3 %
Global electricity demand in 2025/20 with moderate energy efficiency (Greenpeace International Projection)	3,5 %	1,7 %
Global Solar Electricity Output in 2040:	4890 TWh	
Global electricity demand in 2040 (IEA projection)	16 %	
Global electricity demand in 2040 with moderate energy efficiency (Greenpeace International Projection)	24 %	
Detailed Projections for 2025:		
PV systems capacity	433 GWp	205 GWp
Grid-connected consumers world wide	290 million	135 million
Off-grid consumers	1.6 billion	900 million
Employment potential, full-time jobs world wide	3,2 million	1,9 million
Investment value		
Average annual investment value 2005 - 2025	45,2 billion €	30,9 billion €
Investment value in 2025	102,5 billion €	76,1 billion €
Prices for grid connected PV systems; Reduction down to		2 € per Wp
Cumulative carbon savings	2.204 million ton.CO_2	851,5 million ton.CO_2
Annual CO_2 savings	353 million ton.CO_2	165,4 million ton.CO_2

EXECUTIVE SUMMARY

SOLAR GENERATION: PV'S CONTRIBUTION TO GLOBAL ELECTRICITY SUPPLY

The EPIA/Greenpeace scenario shows that by 2025 PV systems could be generating approximately 589 TWh of electricity around the world. This means that enough solar power would be produced globally in twenty years' time to satisfy the electricity needs of 20% of the entire EU-25. Put another way, this would represent the annual output from 150 coal-fired power plants.

Global installed capacity of solar power systems would reach 433 GWp by 2025. About two thirds of this would be in the grid-connected market, mainly in industrialised countries. Assuming that 80% of these systems are installed on residential buildings, and their average size is 3 kWp, the total number of people by then generating their own electricity from a grid-connected solar system would reach 290 million. In Europe alone there would be roughly 41 million people receiving their supply from solar electricity generation.

Although the key markets are now located mainly in the industrialised world, a global shift will result in a significant share – approximately 40 GWp – being taken by the developing world in 2025. Since system sizes are much smaller than grid connected systems and the population density greater, this means that up to a 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.

By 2040, the penetration of solar generation would be even greater. Assuming that overall global power consumption had by then increased from 16,000 to 36,500 TWh, the solar contribution would equal 16% of the world's electricity output. This would define solar power as an established world energy source.

SOLAR GENERATION: PV'S CONTRIBUTION TO INDUSTRY, EMPLOYMENT AND THE ENVIRONMENT

For the solar production industry, global annual shipments of PV modules will rise from 1.4 GWp in 2005 to more than 55 GWp in 2025. This represents an increase by a factor of 40.

For job seekers in 2025, this will contribute considerably towards their employment prospects. On the assumption that more jobs will be created in the installation and servicing of PV systems than in their manufacture, the result is that by 2025 it is likely that more than 3.2 million full-time jobs will have been created by the development of solar power around the world. Most of those would be in installation and marketing.

By 2025 solar PV would also have had one other important effect. In environmental terms, it would have reduced annual CO_2 emissions by 353 million tonnes. This reduction is equivalent to the emissions from Australia **AND** New Zealand, or 150 coal-fired power plants. Cumulative CO_2 savings from solar electricity generation between 2005 and 2025 will have reached a level of 2.2 billion tonnes.

POLICY RECOMMENDATIONS

In order to supply up to a billion people with solar electricity by 2025, and go on to achieve a global electricity share of 20% or more 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,** *an annual world PV market growth of 5GWp+ by 2010 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 on the global photovoltaics industry.*
- **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,** *legally enforceable mechanisms must be implemented to secure and accelerate the new market for solar photovoltaics. Particularly in industrialised and emerging economies, the introduction or expansion of premium feed-in tariffs with guaranteed lifetimes must be a cornerstone of all future promotion mechanisms for solar electricity.*

Our goal now must be to mobilise the necessary industrial, political and end-user commitment to this technology and, more importantly, the service 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.

PART ONE

SOLAR BASICS

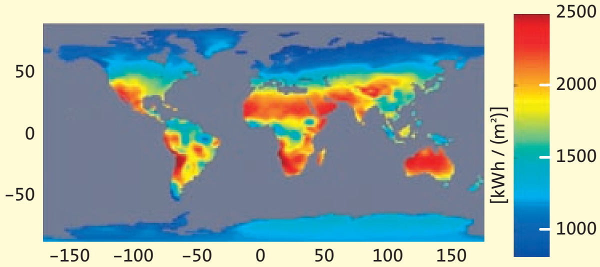
PART ONE: SOLAR BASICS

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 is enough to provide for global energy consumption 10,000 times over. On average, each square metre of land is exposed to enough sunlight to produce 1,700 kWh of power 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.

Figure 1.1: Global variations in irradiation

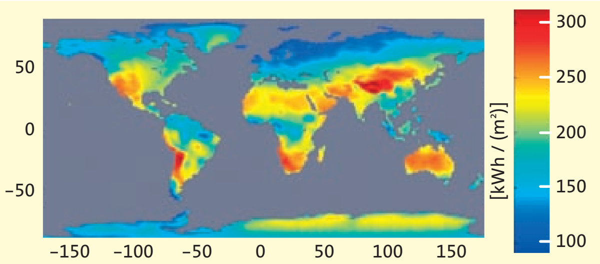


Source: Gregor Czisch, ISET, Kassel, Germany

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

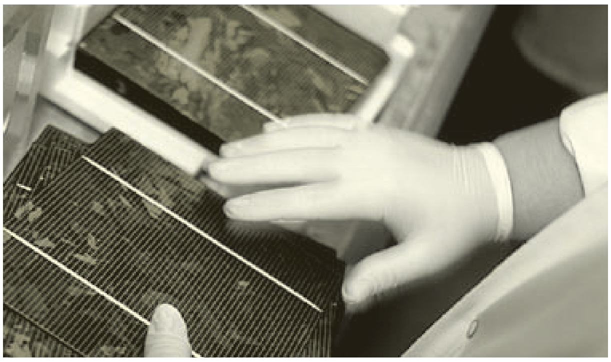
Figure 1.2 shows the estimated potential energy output from solar PV generators in different parts of the world. The calculation used here takes into account the average efficiency of modules and converters as well as the correct angle to the sun required at different latitudes.

Figure 1.2: Energy potential from PV around the world



Source: Gregor Czisch, ISET, Kassel, Germany

In terms of final demand, the report Solar Electricity in 2010 (European Photovoltaic Industry Association, 2001) shows that only the market segment comprising grid-connected PV rooftop systems, the most dynamic growth area in the market, has the potential to generate an average of 16% of electricity consumption across the OECD (industrialised) countries. This is roughly equivalent to today's contribution from hydropower.



WHAT IS PHOTOVOLTAIC ENERGY?

"Photovoltaic" is a marriage of two words: "photo", meaning light, and "voltaic", meaning electricity. Photovoltaic technology, the scientific term used to describe what we use to convert solar energy into electricity, generates electricity from light.

We use 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 (PV) cells is silicon, an element most commonly found in sand.

All PV cells have at least two layers of such 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 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 also generates electricity on cloudy days by a rationing of the energy output that depends on the density of the clouds. 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 SOLAR POWER

- *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.*

PV TECHNOLOGY

The most important parts of a PV system are the **CELLS** which form the basic building blocks of the unit which collects 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 thick **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 (93.5% in 2005) has so far involved the former, while future plans will also 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 in the future. 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 in the laboratory. Solar cell efficiency in the production process and the thickness of the solar cell are important fields for optimisation. Wafers, very thin slices of silicon, are the basis for crystalline solar cells. Thinner wafers mean less silicon needed per solar cell and, as a consequence, lower costs per solar cell. The average thickness of the wafers could be reduced from 0.32 mm in 2003 to 0.24 mm in 2005. In the same period the average efficiency could be increased from 14% to 15%. By 2010 the aim is to reduce the wafer thickness to 0.15 mm while increasing its efficiency to 17.5%.

THIN FILM

Thin film modules are constructed by depositing extremely thin layers of photosensitive materials on a low-cost backing such as glass, stainless steel or a polymer foil. This results in lower production costs compared to the more material-intensive crystalline technology. This price advantage is counterbalanced at the moment, however, by substantially lower efficiency rates and less experience of the modules' lifetime performance.

Several 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) as well as hybrid cells consjsting of an amorphous silicon and a microcrystalline layer (a-Si/m-Si)

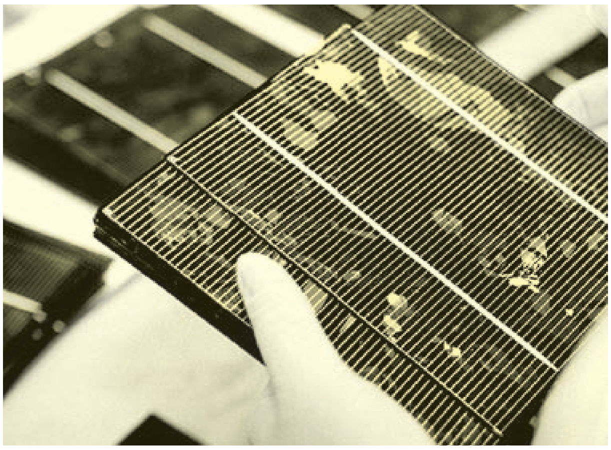
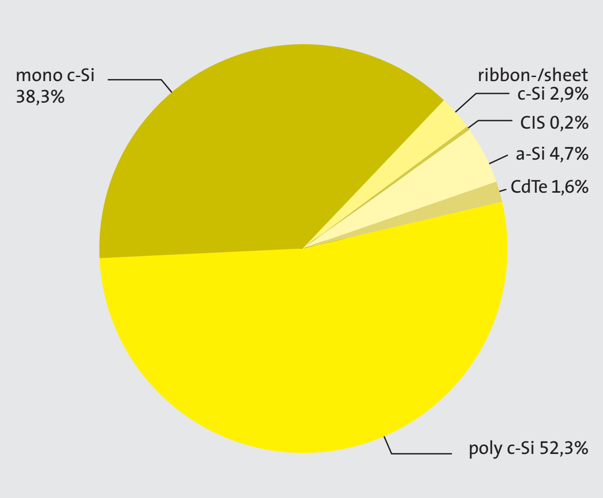


Figure 1.3: Cell technology shares in 2005



Source: "Photon International", March 2006

All of these have active layers in the thickness range of less than a few microns. This approach allows higher automation once a certain production volume is reached, while they all use an integrated approach to the module architecture. This is less labour-intensive compared to the assembly of crystalline modules by interconnecting a number of individual cells.

The temporary shortage of silicon offers the opportunity of increasing market shares for thin film technologies. EPIA expects a growth of the thin film market share up to 12%-20% of the total PV market in 2010.

There are several new companies working on the development of thin film production based on a roll-to-roll approach. This approach means that a flexible substrate, e.g. stainless steel, is coated in a continuous process with layers as used in one of the thin film technologies. The successful implementation of such a production method in the industrial environment offers opportunities for a significantly higher throughput in the factory and lower costs can be expected as a consequence.

Among these three commercially available thin film technologies, a-Si is the most important in terms of production and installation (4.5% of the total market in 2005).

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 focus light from a large area onto a small area of photovoltaic material using an optical concentrator (such as a Fresnel lens), thus minimising the quantity of PV cells required. The two main drawbacks with concentrator systems are that they cannot make use of diffuse sunlight, and must always be directed towards the sun with a tracking system.

PART ONE: SOLAR BASICS

SPHERAL SOLAR TECHNOLOGY uses minute silicon beads bonded to an aluminium foil matrix. This offers a big cost advantage because of the reduced requirement for silicon. Two companies, from Canada and Japan, are planning to commercialise modules with spheral solar cells, with one of them already predicting a module efficiency of 11%. This represents an excellent example of the rapid technical progress in photovoltaics.

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 27 square metres, would produce enough power to meet the electricity demand of an energy-conscious household.

Table 1.1: Module and cell efficiencies

Type	Typical module efficiency (%)
Single crystalline cell [mono c-Si]	12–15
Multicrystalline silicon [Multi c-	11–14
Amorphous silicon [a-Si]	5–7
Cadmium telluride [CdTe]	6–7.5
CIS	9–9.5
a-Si/m-Si	10

Source: International Energy Agency (IEA) Photovoltaic Power Systems Programme,

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 severalhundred kWp

COMPONENTS FOR STAND-ALONE PV SYSTEMS

Stand-alone (off-grid) PV systems contain 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.

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, this is considerably higher that the usual tariff paid by the customer to the utility, so usually all electricity produced is fed into the public grid and sold to the utility. This is the situation in countries such as Germany or Spain.

OFF-GRID

Completely independent of the grid, the system is connected to a battery via a charge controller, which stores the electricity generated and acts as the main power supply. An inverter can be used to provide AC power, enabling the use of normal appliances without mains power. Typical off-grid applications are industrial applications such as repeater stations for mobile phones or rural electrification. Rural electrification means either small solar home systems (SHS) covering basic electricity needs or solar mini grids, which are larger solar electricity systems providing electricity for several households.

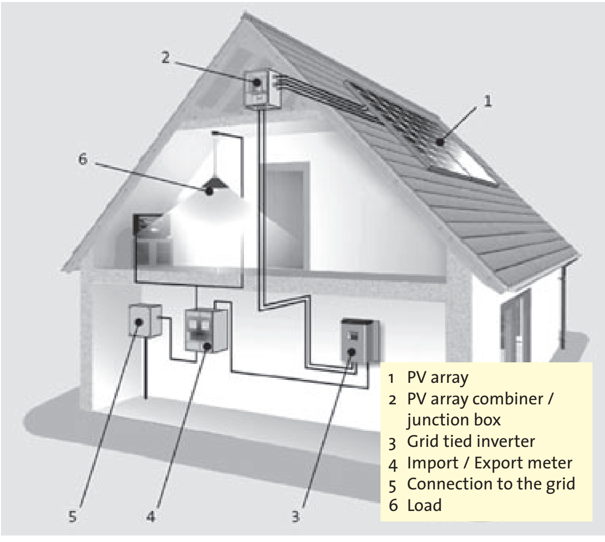
HYBRID SYSTEM

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.

GRID-CONNECTED SYSTEMS:

The massive increase of PV markets worldwide is mainly due to the tremendous growth of grid-connected PV markets world-

Figure 1.4: Grid connected photovoltaic systems – how do they work?



QUESTIONS ABOUT PHOTOVOLTAIC SYSTEMS

1. DO WE HAVE ENOUGH SILICON?

The raw material for pure silicon used in the PV industry is abundantly available worldwide. 23% of the earth's crust consists of silicon. However, the process of producing the pure silicon needed for crystalline solar cells is complex. The period from planning a new silicon factory to its first output is approximately two years. The dynamic development of the PV market led to a shortage of silicon, and the silicon industry reacted to that by building up capacity. As soon as this new capacity is operational, the availability of silicon will improve significantly.

2. IS IT POSSIBLE TO RECYCLE PHOTOVOLTAIC MODULES?

Yes, this is possible. All components of a solar module can be recycled. The most valuable part are the solar cells itself, which can be recycled into new wafers, that are again the basis for new solar cells. But the aluminium frames, the glass and the cables can also be recycled.

3. WHEN DO YOU EXPECT PV TO 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 solar electricity will be cost competitive with peak power from conventional energy sources before 2010.

4. DO PV SYSTEMS GENERATE MORE ENERGY OVER THEIR LIFETIME THAN IS NEEDED FOR THEIR PRODUCTION?

Yes they do. After approximately three years a PV system in southern Europe based on crystalline technology will have generated enough energy necessary to have produced and installed all its components. All energy produced after these three years is a surplus. Over the PV system's lifetime of up to 30 years, it produces far more than the energy used to produce it.

For a thin film system this value is even lower at approximately two years. It is expected that crystalline systems will also achieve equivalent energy production at two years, and that thin film systems will reduce the time further to one year.

wide. But it has to be emphasized that all PV market segments are growing. The principle of grid-connected PV systems is explained in *Figure 1.4*.

The electricity (direct current) generated by the solar cells in the PV modules is transported via normal cables to an inverter. This electrical tool, which is often installed somewhere close to the house's connection point to the public grid, transforms the direct current into alternating current in order to make it compatible with the electricity in the house and the public grid. Then there are two options:

1. *In countries with an attractive feed-in tariff for solar electricity (see* Feed-in tariffs*) all electricity generated will be fed after the inverter directly into the grid. The electricity is thereby sold to the utility. The amount of electricity fed into the grid will be measured by a meter in order to get the correct payment from the utility.*
2. *In countries without an attractive feed in tariff for solar electricity (e.g. a feed-in tariff below the usual consumer prices for electricity) the electricity is in the first place used to cover the electricity demand in the house. By this the electricity bill can be reduced. Only if there is no or not enough demand within the house, the surplus electricity will be fed into the grid.*

THE BENEFITS OF SOLAR POWER

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-connection situations.

SPACE-SAVING INSTALLATION

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 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.

OTHER PLACES WHERE PV CAN BE INSTALLED include the sound barriers along communication links such as motorways. Also areas such as former mining land are suitable for large ground based PV systemsImproving 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 to provide peak power demand..

PROTECTING THE ENVIRONMENT

Solar power involves none of the polluting emissions or environmental safety concerns associated with conventional generation technologies. There is no pollution in the form of exhaust fumes or noise during operation. Decommissioning a system is unproblematic.

Most importantly, in terms of the wider environment, there are no emissions of carbon dioxide - the main gas responsible for global climate change (see *Climate Change and Fuel Choices*) during the operation of a PV system. Although indirect emissions of CO_2 occur at other stages of the life-cycle, these are significantly lower than the avoided emissions. Solar power can therefore make a substantial contribution towards international commitments to reduce emissions of greenhouse gases and their contribution to climate change (see box *The Climate Change Imperative*), if governments adopt a wider use of PV in their national energy generation.

CLIMATE CHANGE AND FUEL CHOICES

Carbon dioxide is responsible for more than 50% of the manmade 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

PART ONE: SOLAR BASICS

THE CLIMATE CHANGE IMPERATIVE

The growing threat of global climate change resulting from the build-up of greenhouse gases in the earth's atmosphere has forced national and international bodies into action. Starting from the Rio Earth Summit in 1992, a series of targets have been set both for reducing greenhouse gas emissions and increasing the take-up of renewable energy, including solar power. Ten years later, however, the World Summit for Sustainable Development in Johannesburg still failed to agree on legally binding targets for renewables, prompting the setting up of a "coalition of the willing". The European Union and more than a dozen nations from around the world expressed their disappointment with the Summit's inaction by issuing a joint statement called The Way Forward on Renewable Energy". Later renamed the Johannesburg Renewable Energy Coalition, more than 85 countries had joined by the time of the Renewables 2004 conference in Bonn and in Bejing at the end of 2005.

The 1997 **KYOTO PROTOCOL,** *now ratified by more than 150 nations, has meanwhile committed the world's industrialised countries to reducing their emissions of greenhouse gases by an average of 5% from their 1990 levels. Kyoto could not come into force unless it was ratified by countries responsible for 55% of the industrialised nations' greenhouse gas emissions. In June 2004 the proportion had reached 44%, with Russia's 17% waiting to tip the balance. In October 2004, the Russian government ratified the Kyoto Protocol, which came into force on 16 February 2005. The first historic meeting of the Parties under the enforced Kyoto Protocol took place in December 2005 in Montreal, Canada. This conference has acknowledged the urgency of the threat that climate change poses to the world's poorest people, and eventually, to all of us. The decisions made here have cleared the way for long-term action. The meeting agreed to do the following.*

- *To start urgent negotiations on a new round of emission reduction targets for the second commitment period of the Kyoto Protocol (2013-2017). A special group has been established to ensure that these negotiations are concluded "as soon as possible". This is necessary to ensure the continuity of carbon markets, and to allow governments to put policies and measures in place to ensure that the new emission reduction targets are met.*
- *o start now to review and improve the Kyoto Protocol. Mandated under the existing treaty, this review will formally begin at next year's meeting.*
- *A Five Year Plan of Action on Adaptation, to assist least developed countries to cope with the impacts of climate change. This programme will begin to address the fact that climate change already impacts the world's poorest people, and that it will get much worse in the coming decades. It is the ethical, political, and legal responsibility of the industrialised countries to provide for this.*

OTHER COMMITMENTS PROMPTED BY CLIMATE CHANGE INCLUDE:

- *The* **EUROPEAN UNION** *has set a target to double the proportion of energy in the 15 Member States (before the 2004 enlargement) provided from renewable sources. The aim is to achieve 12% renewable energy by 2010. This includes a specific target to achieve 3 GWp of PV capacity.*
- *The* **EU** *also has a target for 1 million solar roofs as part of its renewable energy "Campaign for Take-Off" by 2010. Other countries around the world have similar targets for large numbers of grid-integrated PV systems (see "The Solar Race").*

the fossil fuels because it produces roughly half the quantity of carbon dioxide than 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.

- *The proportion of CO_2 in the atmosphere has risen by about one third since industrialisation began.*
- *The number of natural disasters caused by the planet's extreme weather has trebled since the 1960s. According to insurance company Munich Re the resulting economic damage has increased by a factor of nine.*
- *Since 1875 recording has shown that the eight warmest years have been in the past 11 years.*
- *The mass of inland glaciers has been halved since industrialisation began.*
- *Rainfall in temperate and northern latitudes has increased by 5% since 1950.*
- *According to a UN study, the economic damage of climate change will reach an annual figure of €300 billion by 2050.*
- *Sea levels have risen by 10-20 centimetres in the last 100 years, 9-12 cm of this in the last fifty years.*
- *According to a WHO study, as many as 160,000 people are dying each year as a result of climate change.*
- *According to a study published in Nature (January 2004), a mid-range level of warming could result in the extinction of 1,000,000 terrestrial species by the middle of this century.*

Because of the time lapse between emissions and their effects, the full consequences of the climate change to which we have already committed the planet still have to emerge over the coming decades, bringing increased danger to the stability of the world's economy and lifestyle. To effectively stem the greenhouse effect, emissions of CO_2 must therefore be greatly reduced. Scientists believe that, of the fossil energy reserves that can be developed commercially today, only a quarter should be permitted to be burnt if ecosystems are not to go beyond the point at which they are unable to adapt.

ENABLING ECONOMIC DEVELOPMENT

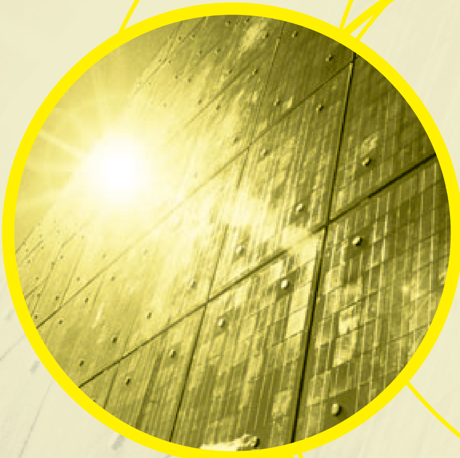
PV offers important social benefits in terms of job creation, energy independence and rural development. Significantly, much of the employment creation is at the installation point (installers and service engineers), giving a boost to local economies.

Solar power can be easily installed in remote and rural areas, places that may not be targeted for grid connection for many years. Installations of transmission and distribution lines are avoided and remote communities can reduce reliance on energy imports.

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 used, especially during the production of solar cells, is seen to far outweigh the electricity 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 three to four years, well below their expected lifetime. With increased cell efficiency and a decrease in cell thickness, as well as optimised production procedures, it is feasible that the EPBT for grid-connected PV will decrease to two years or less for crystalline silicon modules and to one year or less for thin film modules.



PART TWO

THE SOLAR POWER MARKET

PART TWO: THE SOLAR POWER MARKET

Solar power is booming. By the end of 2005 the cumulative installed capacity of all PV systems around the world had reached the landmark figure of 5000MWp. This compares with a figure of 1,200MWp at the end of 2000, reflecting a more than quadrupling of the total installed capacity in just five years. Shipments 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 business only of the European PV industry in 2005 was worth more than € 5 billion. Competition among the major manufacturers has become increasingly intense, with new players entering the market as the potential for PV opens up. Although the expansion in recent years has been primarily in the grid-connected sector, the international PV demand side market divides up into four clear sectors. These market categories are used throughout this report.

DEMAND-SIDE MARKET SECTORS

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, and to provide power for services such as water sprinklers, road signs, lighting and phone boxes.

Typical of a new development 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

As demand for a mobile electricity supply increases, it is likely to continue to grow, especially with the attraction of innovative low-cost solar electricity technologies such as organic solar cells.

GRID-CONNECTED SYSTEMS

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 more than 2,700 kWh/year, sufficient to supply up to 100% of the electricity needs of an energy-conscious household.

PV is also used increasingly as a design feature by architects, replacing elements in a building's envelope. **SOLAR ROOF TILES OR SLATES** can replace conventional materials, for instance. Flexible thin film modules can even be integrated into vaulted roofs, while 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.

Large-scale grid-connected PV arrays have not so far become a major part of the market, mainly because of the difficulty in finding enough space in built-up areas. In Europe, however, it was estimated in 1998 that the potential for integrating PV into noise barriers then planned for construction alongside motorways and railways was as high as 1,100MWp. Sun-drenched desert regions present good opportunities in the longer term, 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 new source of income for farmers, who can rent their land to investors in large PV systems, with the advantage of secure revenue for at least 20 years.

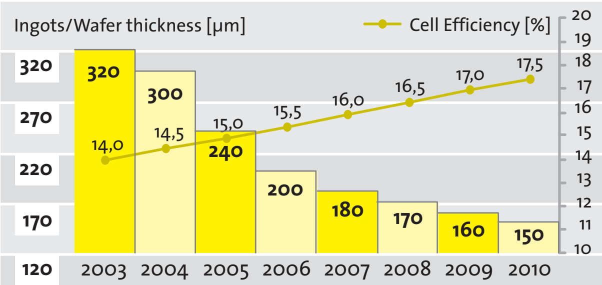
MARKET DEVELOPMENT

This sector 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. While in 1994 only 20% of new capacity was grid-connected, this had grown to over 80% by 2005.

Examples of market stimulation programmes include Japan's 70,000 rooftop proposal, the 100,000 roofs initiative in Germany, the current Renewable Energy Law in Germany, and the million solar roofs programme in the United States, which includes both PV and solar thermal applications. These support programmes will continue to provide an impetus for market growth for some years to come, and are likely to be followed by similar initiatives in other countries (see *The Solar Race*).

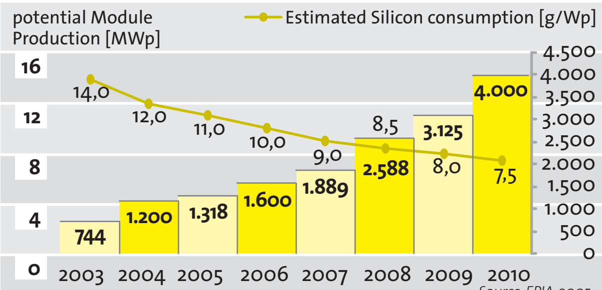
The other side of the grid-connected domestic market is the control which PV systems allow the consumer over their power supply. Not only is electricity generated at the point of demand but the consumer is effectively transformed into the operator of his or her own power station. As international power markets steadily liberalise this is likely to have increasingly important market implications.

Figure 2.1: Ingots / Wafer Thickness and Cell Efficiency in g/Wp depending on potential module production [MWp]



Source: EPIA, 2005

Figure 2.2: Estimated Silicon consumption in g/Wp and potential Module Production [MWp]



Source: EPIA, 2005

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.

PV can provide electricity to both consumption and production uses, where the majority of applications directly contribute to achieving the Millennium Development Goals. Domestic energy systems provide high quality lighting and communication (radio/TV/internet) and productive energy systems such as for cooling, water pumping or powering tools are crucial motors for local development. PV has the potential to deliver much more than just electricity for lighting or improved health care, however. By providing the **POWER SUPPLY FOR COMPUTERS**, for example, it can enable people not just to have access to information through the internet, but to improve their economic situation through better marketing of products or buying goods at more reasonable prices.

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. But 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.

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.

OFF-GRID INDUSTRIAL

APPLICATIONS

Industrial uses for off-grid solar power are mainly 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. **REPEATER STATIONS FOR MOBILE PHONES** powered by PV or hybrid systems (PV/diesel) also have a large potential.

Other applications include traffic signals, marine navigation aids, security phones, weather or pollution monitors, remote lighting, highway signs and waste water treatment plants.

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.

SUPPLY SIDE MANUFACTURE

SOLAR GRADE SILICON

Silicon is the basic material needed today for the production of solar cells based on crystalline technology. Solar cells based on crystalline technology cover more than 90% of the world market, therefore the availability of sufficient silicon at reasonable prices is an essential precondition for a dynamic PV industry. Until recently the silicon industry produced electronic grade silicon exclusively for the semiconductor industry, according to its needs. Only a small fraction of the annual silicon supply was delivered to he PV industry, which represented a good way to level out the significant demand fluctuations from the semiconductor industry. But the production of the electronic grade silicon never aimed at satisfying the demand from the PV industry. With the dynamic growth of the PV industry in recent years the situation has changed. By now one third of the worldwide production of electronic grade silicon is used to produce solar cells. It is very obvious that this growing demand has changed the identity of the PV industry into a highly interest-

ing client for the silicon industry. Several companies have begun to develop processes for producing solar grade silicon. Solar grade silicon is of lower quality than electronic grade silicon, since solar cells do not require as high a quality of silicon as semiconductor elements in the computer industry do. Therefore solar grade silicon can be produced at lower cost. But the development of the solar grade silicon production process and the construction of the first factories still needs time. The silicon industry is currently building up capacity to produce solar grade silicon which will be exclusively available to the PV industry.. But until all the new planned production facilities for solar grade silicon are operational the PV industry is competing with the semiconductor industry for the currently limited silicon available on the market.

It is expected that in 2008 the availability of solar grade silicon for the PV industry will lead to a much more relaxed situation on the silicon market.

SOLAR CELL AND MODULE PRODUCTION
In 2005 the investment in new plant in order to manufacture solar cells and modules exceeded €800 million. Also in 2005, the PV industry raised more than €1.5 billion on capital markets over 27 recorded financial transactions (source: Marketbuzz 2006 .

These numbers underline the clear dynamic which the PV industry is developing in order to quickly expand supply in this world market.

In previous years the manufacture of solar cells and modules was concentrated in three key areas – Europe, Japan and the United States. The most recent leading player is China.

The shipment numbers presented in this chapter are based on the Photon International survey published in March 2006. In their introduction the authors admit that the data they received from the producers in many cases seemed to be too optimistic. The EPIA estimation for 2005 solar cell shipment is1400MWp, which corresponds to 77% of the total world shipment of 1818MWp stated by Photon International. For this reason all data with the unit MWp given in the following market survey correspond to 77% of the data published by Photon International. The evident drawback of this procedure is that the market share of those companies and countries/regions that contributed correct numbers to the survey has been underestimated.

Japan still leads the world, with solar cell shipments reaching 635MWp in 2005. This corresponds to 45.3% of total world production. Europe came second in 2005 with 397MWp, corresponding to 28.3% of world production. Production in the United States reached 119MWp, corresponding to 8.5% of world production. The new player China reached 116MWp, corresponding to 8.3% of world production. The rest of the world, with its key players in other Asian countries (e.g. Motech in Taiwan with 46MWp in 2005) and India, produced 133MWp in 2005. It is striking that in 2005 India dramatically lost half of its market share compared to 2004 and was the only country to experience a decrease in solar cell production in 2005. Overall, the growth of global PV shipments since 1995 can be seen in *Table 2.1*.

The leading manufacturers of solar cells can be seen in Table 2.2. 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. In 2005, the two leading producers of PV cells/modules were Sharp (Japan) and Q-Cells (Germany). Compared to the previous year Sharp has lost roughly 2% of its market share (23.5% in 2005) while Q-cells, the new number two in the ranking, increased its market share by more than 50% and in 2005 produced about 9% of the world's total cell shipments. A breakdown of the main companies' involvement in regional and country markets can be seen in *Table 2.2*.

Europe has seen an expansion in production from traditional cell producers such as Schott Solar, which increased its cell production from 44MWp in 2003 to 63MWp in 2005, and Isofoton, which increased from 35MWp in 2003 to 40.8MWp in 2005. New players in the market are also showing impressive growth rates. The German company Q-Cells, for example, expanded its production from 28MWp (2003) to 127MWp (2005), while Deutsche Cell expanded from 17MWp (2003) to 29MWp (2005).

An important issue for manufacturers, especially smaller companies who do not have the backing of a multinational parent, 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 like the German renewable energy law (see *Part Three: The Solar Race*) 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. During the period of the 100,000 roofs programme, from 1999 to 2003, more than €1 billion was invested in new production facilities. Further encouraged by the Renewable Energy Law, updated in 2004, production of PV cells increased from 32MWp (2001) to 312MWp (2005) (Source: BSW) and it is anticipated that cell production capacity will increase to 500MWp by the end of 2006.

This reducing factor was introduced by EPIA in order to level out the sometimes over-optimistic shipment data provided by some of the cell producers. However it is evident that by this method that the production of those companies that provided correct shipment data to the survey has been underestimated.

MANUFACTURING AND OPERATING COSTS

The cost of manufacturing both solar cells and modules and other components has been falling steadily. As a result, the price of PV systems has fallen by an average of 5% per annum over the last 20 years. It is expected that this rate of price decrease can be maintained in the future when as the shortage of silicon is over. The shortage of silicon and its consequence of

Table 2.1: PV cell manufacture – leading producers by region

	Total shipments in 2005	Growth from 2003	Leading producers	Shipments in 2005
Europe	397 MWp	96%	Q-Cells (Germany)	127.6 MWp
			Schott Solar(Germany)	63.1 MWp
			Isofoton (Spain)	40.8 MWp
			Deutsche Cell (Germany)	28.9 MWp
			Photowatt (France)	25.1 MWp
			Ersol (Germany)	15.4 MWp
			Scancell (Norway)	15.4 MWp
			Shell (Germany)	13.1 MWp
			BP Solar (Spain)	13.0 MWp
			Sunways (Germany)	12.3 MWp
Japan	635 MWp	73.8%	Sharp	292 MWp
			Kyocera	109.3 MWp
			Mitsubishi Electric	77 MWp
			Kaneka	16 MWp
			Sanyo	96.3 MWp
United States	119 MWp	23.6%	Shell Solar	32.3 MWp
			United Solar	16.9 MWp
			First Solar	16.2 MWp
			BP Solar	15.8 MWp
			GE	13.9 MWp
			Evergreen	10.8 MWp
			Schott Solar	10.0 MWp
China	116 MWp	1200%	Ningbo Solar Cell Factory	19.25 MWp
			Shenzhen Topray Solar	15.4 MWp
			Suntech Power	63.1 MWp
Rest of the World	133 MWp		Motech (Taiwan)	46.2 MWp
			BP Solar (Australia)	27.1 MWp
			E-Ton Dynamics	10.8 MWp
			BP Solar (India)	10.2 MWp

Note: This table includes manufacturers with shipments over 10MWp in 2005 Source: Photon 03/2006 Note: all data given in the table represent 77% of the value given in the Photon International Survey.

Table 2.2: Growth in world PV cell production 1996-2005 (MWp)

Region	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Japan	21.20	35.00	49.00	80.00	128.60	171.22	251.07	363.91	604	635
Europe	18.80	30.40	33.50	40.00	60.66	86.38	135.05	193.35	329	397
US	38.85	51.00	53.70	60.80	74.97	100.32	120.60	103.02	138	119
China										116
ROW	9.75	9.40	18.70	20.50	23.42	32.62	55.05	83.80	38	133
Total	88.60	125.80	154.90	201.30	287.65	390.54	561.70	744.08	1100	1400

Source: PV News, Photon International, IEA PVPS (except 2005)

PART TWO: THE SOLAR POWER MARKET

the rise in material costs has the effect that at present the 5% price decrease per annum is not being realised. Prices for PV systems vary between countries and according to the level of market development in different regions of the world, but an average price estimate for a turnkey solar electricity system of a few kWp capacity would be €6000/kWp for grid-connected systems and about €8,500 for stand-alone systems. This would result in life-cycle running costs for solar electricity ranging from €0.19/kWh up to €1/kWh, depending on the available insolation and financial assumptions. These costs make PV an economically advantageous choice in a large variety of applications where no mains electricity is available.

By contrast, the grid-connected market must still depend for the moment on government incentive programmes. In Japan, however, where subsidies were cut dramatically by 50% in March 2004 and to almost zero in 2006, the level of applications for PV systems to the New Energy Foundation continued to remain at the same level in the immediate aftermath of the cut. This suggests that the market has already reached a substantial level of sustainability as a result of the former incentive programmes, a pattern that can be expected to repeat itself in other countries with expanding markets.

As with any technology, the development of a learning curve leads to cost reductions. In the case of PV the cost decrease is expected to be around 20% every time the total installed capacity is doubled.

TECHNOLOGY IMPROVEMENTS

The production of PV cells is constantly improving as a result of both technology advances and changing industrial processes. About 70% of installation costs are represented by the module, 15% by the inverter and 15% by balance of system components and assembly of the unit.

As larger PV cell and module factories come into operation, the degree of **AUTOMATION IN THE PRODUCTION PROCESS** *is increasing. A number of European solar cell producers have developed highly automated solar cell plants since 2001. The fact that the 1999 cell production capacity in Europe was just 80MW, while at the end of 2005 production capacity in Germany alone was up to 500MWp clearly indicates the potential for automation and major improvements in the production process.*

Conventional methods of **CELL PRODUCTION** *produce a wafer from bulk silicon crystal through a cost-intensive and material-inefficient sawing process. Losses during the transition from ingot to solar cell reach about 50%, mainly in the form of saw slurry. One way of eliminating the sawing step is to grow ribbons of multicrystalline silicon that are already wafer thin and the correct width for use as PV cells. This method is being pioneered by Schott Solar at one of its factories. EPIA has adopted the following technological aims in this field for 2010 (with its projection for 2020):*

- *Material (Si) consumption for mono-crystalline silicon from 16 gram per Watt peak [g/Wp] to 10 g/Wp (continuing to 8 g/Wp)*
- *Ribbons from 10 g/Wp to 6 g/Wp (continuing to 5 g/Wp)*
- *Wafer thickness from 300 mm to 150 mm (continuing to 100 mm)*
- *Kerf loss in the sawing process from 250 mm to 160 mm (continuing to 150 mm)*

Since the first solar cell was developed 50 years ago **MAJOR IMPROVEMENTS IN EFFICIENCY** *have been achieved. With much potential still to be exploited, EPIA has defined the following aims for the European PV industry up to 2010 (2020):*

- *Efficiency increase for mono-crystalline silicon from 16.5% to 20% (continuing to 22%)*
- *Efficiency increase for multi-crystalline silicon from 14.5% to 18% (continuing to 20%)*
- *Ribbon efficiency from 14% to 17% (continuing to 19%)*

Improvement in the **LIFETIME OF SOLAR MODULES** *is another road to further reducing solar electricity prices. EPIA's aim is to expand their lifetime to 35 years, for example by longer lifetime encapsulation material or new module architectures.*

THIN FILM CELLS, *constructed by depositing extremely thin layers of photosensitive materials on a low-cost backing, offer the potential for significant cost reductions. Firstly, material and energy costs should be lower because much less semiconductor material is required and much lower temperatures are needed during manufacture. Secondly, labour costs are reduced and mass production prospects improved because, unlike thick crystalline technologies where individual cells have to be mounted in frames and wired together, thin films are produced as large, complete modules.*
EPIA has defined two targets for thin film technology up to 2010 (2020):

- *Thin film aiming at efficiencies between 10% and 12% (a-Si/mc-Si, CIS and CdTe) (continuing to 15%)*
- *Building integrated PV (BIPV) with low cost per m2, price reduction of 50% (continuing an additional 50%)*

PART THREE

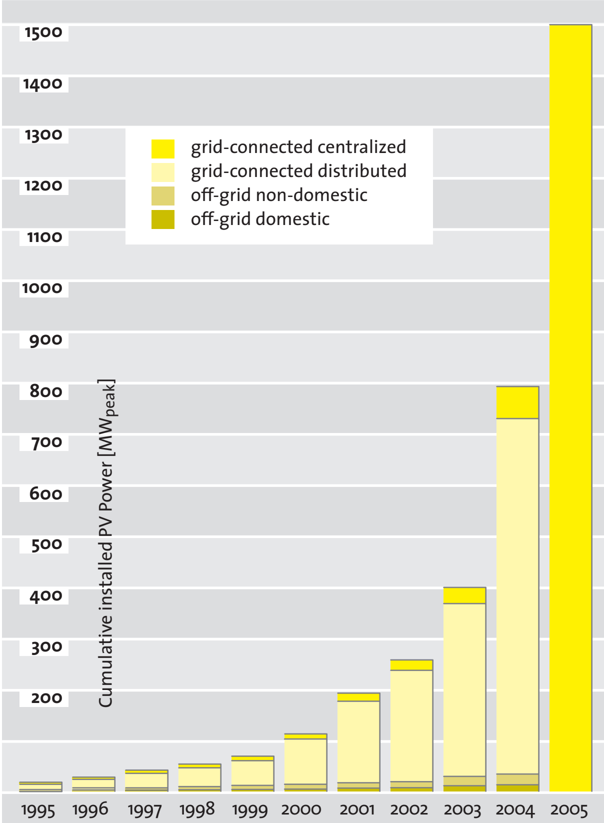
THE SOLAR RACE

PART THREE: THE SOLAR RACE

As the vast potential of solar power as a clean energy source begins to emerge, national governments around the world have started to support its development through research and market support. Pursuing their regional and international commitments to combat the effects of climate change, a number of countries have given strong backing to an emerging solar market. Importantly, they have also persuaded their general public that there are important social and environmental benefits to be captured.

The argument in countries like Japan, Germany and the USA is straightforward: by offering market incentives for the installation and operation of solar arrays, a dynamic relationship is created between market promotion and industrial growth, eventually encouraging a flourishing manufacturing base and export potential. The environmental dividend is a cleaner planet. These are the leaders in a solar race that will soon see others joining the pursuit.

Figure 3.1: Installed PV in Germany by sub-market



Source: IEA- PVPS (exept 2005)

GERMANY

- *PV capacity end 2005:1500MWp*
- *Support system: Premium price per kWh, financing opportunities from the German Bank for reconstruction*

Germany is the European leader in solar energy. Having already developed the world's largest installed capacity of electricity-generating wind turbines, Europe's most populous state is now looking to push photovoltaics into an equally prominent position.

In terms of installed capacity, Germany overtook the USA in 2001 to achieve second position globally behind Japan. At the end of 2005 total capacity had reached 1500 MWp, with 700MWp installed last year alone. In the 2001 edition of Solar Generation it was ambitiously estimated that the country could achieve a figure of 920 MWp by 2005. This has in fact been almost reached by the end of 2004, and with the expectation that more than 2000 MWp will be installed by the end of 2006.

At the background to this success is the German Social Democrat/Green government's Kyoto-led commitment to reduce its emissions of greenhouse gases by 21% over the period 1990 to 2008-11. This will be achieved by a mixture of shifting energy production towards cleaner sources and a programme of energy efficiency. Two successive pieces of legislation have been crucially important in supporting the first of these aims – the 100,000 roofs programme started in 1999 and the 2000 Renewable Energy Law, updated in 2004. One result is that the wind energy industry has seen a capacity of over 15,000MW installed, representing roughly 5% of electricity supply, and an estimated 45,000 jobs created in less than a decade. The German solar industry has now started a similar boom for PV.

THE ROOFTOP PROGRAMMES

Germany has been a pioneer in grid-connected PV, with an extremely effective "1,000 Rooftop Programme" running from 1990 to 1995. More than 2,250 rooftop installations were con-

Table 3.1: PV feed-in tariffs under REL from 2008

Year	2004	2005	2006	2007	2008
Roof	57.4 €ct**	54.53 ct	51.80 ct	49.21 ct	46.75 ct
Above 30 kW	54.6 ct	51.87 ct	49.28 ct	46.82 ct	44.48 ct
Above 100 kW	54.0 ct	51.30 ct	48.74 ct	46.30 ct	43.99 ct
Facade bonus	5.00 ct	5.00 ct	5.00 ct	5.00 ct	5.00 ct
Open space	45.7 ct	43.42 ct	40.60 ct	37.96 ct	35.49 ct

Note: Rates reduce by 5% per year from 2005 onwards, by 6.5% per year for PV in open space/fields from 2006 onwards

THE REST OF EUROPE

- **SPAIN** *has an overall target to double its proportion of renewable energy to 12% by 2010. The 1998 feed-in law was revised in March 2004, with some significant changes and new conditions that should be excellent tools for getting the PV market moving. These include:*
  - *44 €cents/kWh (valid for 2006) up to system sizes of 100 kWp (until 400MWp installed, then new calculation of the tariff for further systems)*
  - *22.9 €cents/kWh for system sizes above 100 kWp (until 200MWp installed, then new calculation of the tariff for further systems)*
  - *payment period fixed at 25 years, after that the tariff is reduced to 80%. As a consequence the market size grew from approximately10MWp in 2004 to 20MWp in 2005.*
  - *the objective of the government is to reach 400 MW installed PV capacity by 2010*
- **ITALY** *has introduced a feed-in tariff for solar electricity in summer 2005. In the first application slot at the end of September the applications for more than 100MWp were over-subscribed. This clearly states the huge interest in solar electricity. In 2006 Italy will probably become the second largest PV market in Europe behind Germany.*
- *The* **UNITED KINGDOM** *had 5.9MWp of capacity installed by the end of 2003, mostly the result of capital grants totalling €56 million offered by the government.*
- *After several years of regional programmes Austria had a national feed-in tariff at the beginning of 2003. Due to the very limited installed capacity (15MWp) that applied to this law applications were only accepted for less than one month. At the moment there is no national regulation.*
- *In* **GREECE** *In GREECE according to the new renewable energy law that was voted in June 2006, there is a feed in tariff for electricity produced renewable energy technologies. Sale prices of "solar electricity" vary between € 0.40 - 0.50/kWh depending on the installed capacity of the pv system and the area where this system is installed. Prices that are guaranteed for twenty years are increasing annually according to the annual increase of electricity prices.*

The new law is expected to trigger massive investments in solar technologies during the next years.

- **OTHER EUROPEAN COUNTRIES** *are also pursuing solar programmes, mainly targeted at the grid-connected sector.*

nected to the grid during this period, with an average capacity of 2.6 kW per roof. In 1995, total system costs averaged €12.27/W and produced an average 700 kWh per kW installed over the year. At the end of this programme the German PV market suffered a significant breakdown, however, and Greenpeace and other organisations started extensive lobbying work to encourage a follow-up. Greenpeace launched a solar pioneer programme in 1995 and has continued since then with extensive information work in favour of solar PV. Between 1995 and 1999 about 40 cities and towns also implemented their own "rate based" incentive schemes. These allowed residential customers to sell electricity from their rooftop PV systems to the utility for up to €1.02/kWh. The purchase price was usually supported by a 1% levy on electricity sales, mostly introduced after a vote among local electricity customers. This support was eventually superceded by the national Renewable Energy Law.

In 1999, a new five-year programme was launched to promote the installation of PV on 100,000 German roofs, with a budget of €460m. The aim was to develop a total generating capacity of 300MWp. For both private households and businesses the incentive came through a guaranteed ten-year low interest loan (1.9% per annum), with no repayments in the first two years. Such loans were considered a proven method of avoiding PV's currently high start-up investment costs.

Although initial reaction to the "100,000 Roofs" programme was disappointing, the new Renewable Energy Law (REL) introduced in April 2000 accelerated the market dramatically. Under the REL, anyone who installed a solar electricity system received a buy-back rate of €0.5 per kWh over 20 years. This payment then reduced by 5% each year from 2001 onwards for newly installed systems, a fall intended to mirror the anticipated reduction in the price of PV.

This combination of the solar roof programme and the REL has proved a potent mix. Such was the overwhelming response that the 2000 PV loans budget of €92m was already used up by the almost 4,000 applications approved during the first quarter of the year. Thousands more applications had to be postponed due to lack of funds. During 2000 alone more than 8,000 systems were approved, with a total capacity of 41.66MW. The average size also increased to 5.18 kWp, with over 100 plants in the 50 to 120 kWp range – a sign that the market was moving into the business/industrial sector. With the ending of the 100,000 roofs programme the Renewable Energy Law was revised (see *Table 3.1*). Even after the end of the 100,000 roofs programme there are possibilities for loans at low interest rates for investing in a PV system, e.g. the CO_2 abatement programme.

The outcome of the 100,000 roofs programme (1999-2003) with support from the Renewable Energy Law from 2000 - is impressive:

- *345.5MWp installed*
- *Total investment by customers €1.77 billion*
- *Market volume increase from 12MWp in 1999 to 130MWp in 2003*
- *PV system price reduction of 20%*
- *Investment by the PV industry of €1 billion*

FUTURE PROSPECTS

The German government, strongly supported by public opinion, clearly considers PV to be a viable long-term option for production of carbon-free power. Public funding of R&D, about €17.25 million in 2003, is therefore likely to continue. Its focus will be firstly on reducing the costs of solar cell and module production, and secondly on improving the efficiency and reliability of systems. Most importantly, the Renewable Energy Law has provided a secure, medium-term planning base for investment, at the same time helping to move the technology forward from small-scale manufacturing for niche markets to mass production for a broad range of applications.

PART THREE: THE SOLAR RACE

USA

- *PV capacity end 2005: 470MWp (approximately)*
- *Support system: Federal tax credit plus separate state incentives*

Since 1995 the US PV industry has been growing at an average annual rate in excess of 20%. Both the industry and the government's Department of Energy see this trend continuing or accelerating in the future as PV becomes more established as a preferred technology in key markets. The manufacturing industry's goal is to sustain 30 to 35% annual growth over the next 20 years. In terms of installations, PV has reached a level of 470MWp. We estimate that 90MWp were installed in 2004 and 105 were installed in 2005.

The past few years have brought big and mostly positive changes for the US solar industry. With the passage of a much-expanded federal investment tax credit and expanding state solar programmes, solar power is now cost-competitive with retail electricity in a growing number of states. The state programmes, which require over seven gigawatts (GWp) of solar installations by 2020, are providing substantial long-term support to this fast-growing industry. If the federal tax credit can be extended, and the current silicon shortage is eliminated as expected, the future of solar energy in the United States will be brighter than ever.

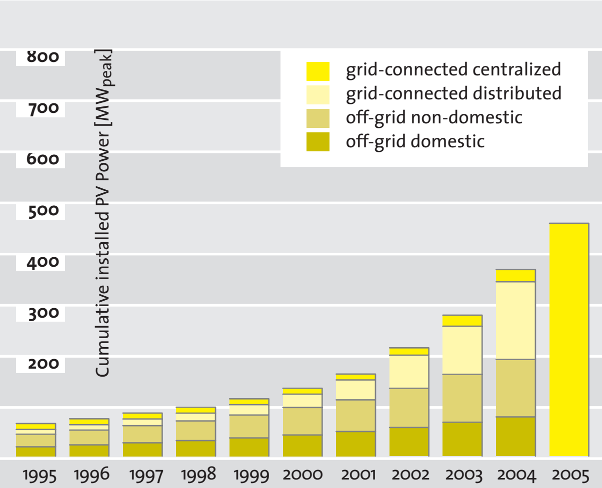
FEDERAL POLICIES, FINALLY!

ENERGY POLICY ACT OF 2005, TAX CREDIT

Although the Energy Policy Act of 2005 was a big step backward for the United States energy policy, it did include some positive elements. The most important sections were the tax credits for renewable energy. On the solar side, the act included a 30% tax credit for individuals and businesses that install solar energy systems, with a $2,000 cap on residential solar installations.

The credit is scheduled to return to 10% for commercial installations, while the residential credit will expire at the end of 2007, just when the solar panel shortage in the United States will begin to ease. The prospects for an early extension of the tax credit are strong. Several legislative vehicles have been introduced in the House and Senate already, including some that have strong bipartisan support.

Figure 3.3: Installed PV in the United States by sub-market



Source: IEA- PVPS (except 2005)

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. First announced during President Bush's State of the Union address in 2006, the initiative aims to make solar power competitive with existing sources of electricity in 10 years. The programme aims to deploy five to ten GWp of capacity, which is in line with the growth projected by industry and promoted by state incentives. The president has proposed a 78% budget increase to $148 million for solar research and development budget. 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. Led by California, New Jersey, Pennsylvania and Arizona, the states have currently committed to fund the installation of over 7 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.

Table 3.2: Summary of State Solar Goals

State	Status of Programme	Commitment by 2020*
Arizona	Commitment under review	900
California	Passed programme (2006)	3,000
Connecticut	Existing	15
Colorado	Passed RPS (2004)	50
District of Columbia	Passed RPS (2005)	30
Hawaii	Existing	15
Nevada	Existing	500
New Jersey	Passed RPS (2006)	1,500
New York	Passed RPS (2004)	25
North Carolina	Existing	10
Pennsylvania	Passed RPS (2004)	860
Rhode Island	Existing	5
Texas (Austin)	Existing	100
Other States*	Programmes in varying states	300
Total		7,310

** Other states: AK, DE, FL, IL, MA, MD, MN, OH, MI, ME, MA, MT, NM, OR, and VT.*

STATE POLICIES ADD UP…

CALIFORNIA

In 2005 California consolidated its place as the leading solar state with the adoption of the California Solar Initiative (CSI) by the California Public Utilities Commission. The CSI is the largest solar power programme in the country, committing a combined $3.2 billion in funds to provide incentives for a million solar installations over the next 11 years. The programme provides rebates for homeowners, businesses, farms and government projects investing in solar power systems. The goal is to install 3,000MW of solar power and in so doing regain California's position as a world leader in solar power while also lowering prices to the point at which government rebates are no longer needed to drive demand.

NEW JERSEY

In April 2006, the New Jersey Board of Public Utilities (BPU) approved a major expansion of the state's Renewable Portfolio Standard (RPS). The rule requires that 2% of electricity comes from solar electric resources - about 1,500MW. Overall, the standard requires that 20% of the state's electricity comes from new renewable energy sources by 2020.

PENNSYLVANIA

In November 2004, Pennsylvania passed a Renewable Portfolio Standard that requires 0.5% or 860MW of solar power to be produced in the state by 2020. The law requires 8% of the state's electricity to come from renewable resources.

ARIZONA

On Feb 27, 2006, the Arizona Corporation Commission approved a revised Environmental Portfolio Standard, which is currently under review by the Arizona Attorney General's office. The new Standard increases the renewable energy requirement to 15% by 2025, of that 900MW (30%) would come from distributed generation resources, most of which is expected to be solar electricity. A final decision is expected in summer 2006.

NEW MEXICO

In February 2006, Governor Bill Richardson signed Senate Bill 269, which creates a 30% tax credit, up to $9,000 for each system, for residential and agricultural solar systems. The bill expands the federal tax credit, which is limited to $2,000 and adds certainty by extending it for 10 years.

The state's largest electric utility, Public Service of New Mexico, has agreed to pay customers $0.13 per kWh of solar power they generate, regardless of whether the electricity goes into the home. This amounts to a $0.21 subsidy to customers who install solar panels and is America's first feed-in tariff, modelled after a highly successful programme in the relatively more cloudy Germany. The utility plans to develop a commercial incentive programme soon.

COLORADO

In 2004 Colorado citizens passed the first Renewable Portfolio Standard by citizen ballot initiative in the United States. The RPS requires 15% renewable energy by 2015, 4% of which must be solar. The state's largest utility company, Xcel Energy, recently initiated a $4.50 per watt residential rebate programme.

NEVADA

Last year, Nevada increased the state renewable energy standard to 20% by 2015, where of that 5% must come from solar PV. To meet the goal, SunEdison, a solar company that leased office space from Greenpeace when it was starting out, announced this year that it would develop the world's largest solar project in Nevada. The 18 megawatt project almost doubles what is currently the world's largest PV project, a 10-megawatt facility in Germany. In addition, SolarGenix is developing the first concentrated solar power plant in Nevada as a result of the RPS, a 65MW plant that will be the first solar thermal power plant built in the United States since the mid-1980s.

WESTERN GOVERNORS ASSOCIATION

The Western Governors have committed their states to developing 30,000MW of clean and diversified energy by 2015. The Solar Task Force made recommendations to the governors on specific policies to facilitate the development of 4,000MW of concentrating solar power, 4,000MW of distributed photovoltaics and 2,000MW of solar hot water.

CITY AND LOCAL COMMITMENTS

SAN FRANCISCO COMMUNITY CHOICE ENERGY

For years Greenpeace has been working with San Francisco to make the dream of large-scale renewable energy a reality. In 2004, the San Francisco Board of Supervisors unanimously passed an Energy Independence Ordinance, bringing the city one step closer to this goal. The stated purpose of the ordinance is to provide "clean, reasonably priced and reliable electricity" to its customers and to fulfill the "public mandate" for "rapid and large-scale development of renewable energy and conservation resources" in San Francisco. If successful, the city would create one of the world's largest urban solar facilities and 360 megawatts of renewable energy, enough to power half the city's needs.

OTHER CITIES

The City of Austin has a goal of installing 100 megawatts of solar power to help meet 15% of its generation needs through renewable energy by 2020. After several years of pressure from Greenpeace, San Diego set a goal of 50 megawatts of solar energy in 2003. The city recently signed a deal to install the first five megawatts of solar on city facilities this year.

UNIVERSITY COMMITMENTS

Students in California and across the country have successfully lobbied their universities to go solar. Last year California State University became the last of the three big California University systems to agree to install solar panels on campus. California State University joined the University of California and Los Angeles Community College District in pledging to install significant onsite renewable energy. Greenpeace has been working with students in California and on other campuses to bring this to fruition.

JAPAN

- *PV capacity end 2005: 1423MWp (1132MWp at the end of 2004)*
- *Support system: Various government programmes, including grants for domestic PV roofs, support for R&D for industrial mass application, and net metering support provided by utilities*

Renewable energy is seen as an indispensable part of Japanese climate change policy and carbon reduction targets, as well as an emerging technology to be exploited. Various supportive policies to encourage growth in the renewables market have been introduced by the government, including significant solar research and development programmes from the 1970s onwards. These policies have received backing from across the spectrum of public bodies, academics, NGOs and the business community. Japan now has PV systems on thousands of schools, hospitals, factories, warehouses, offices, houses and railway stations.

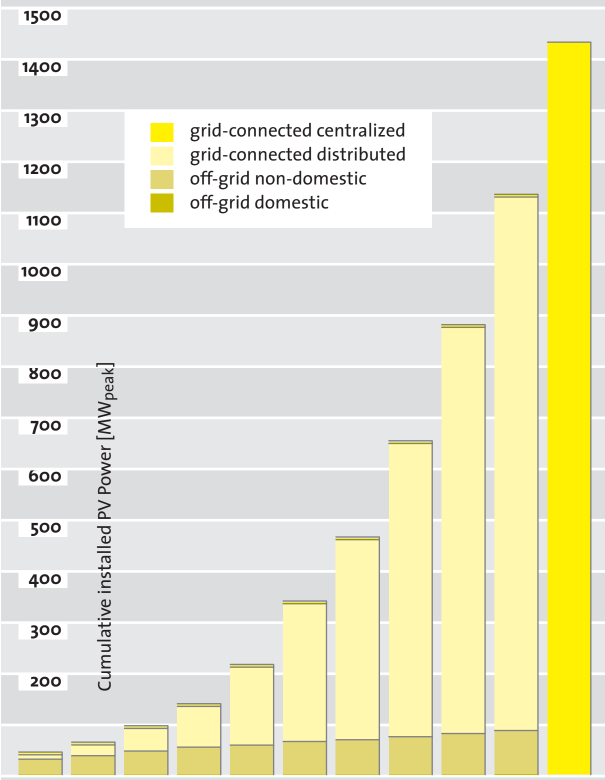
By the end of 2005 a total of 1423 (rough estimate)MWp had been installed in Japan, with government plans for 4.82 GWp by 2010, an ambitious target requiring an annual growth rate of 30%. The annual growth rate since 1998 has been up to 45%, however. If the current trend continues, 70 to 80% of installations in Japan will be rooftop systems with an average size of 3.8 kWp, and the government is seeking to increase the share of industrial application by shifting its support to that end.

The national Japanese programme is shifting its aim from rapid expansion in the number of units in home application sector coupled with a decreasing percentage of subsidies, to the volume of units in the industrial sector. The overall goal is to stimulate production, bring prices down, create market awareness and leave Japanese industry with a fully economic market that will encourage competitive exports to the rest of the world. In pursuit of these objectives, the budget for the residential PV system dissemination programme was continuously cut by 50%, from $223 million in 2002 to $50 million in 2004, and came to an end at the end of the 2005 fiscal year. This reduced the subsidy per kWp from $862/kWp in 2003 to $181/kWp in 2005, and no governmental financial support is available for home application now. Even so, the market has continued to grow, the number of subsidy applications increased during 2003, while the price for PV installed capacity has continued to fall to a present level of about $6,000/kWp. One specific result is that the Metropolitan Government of Tokyo and Tokyo Waterworks installed PV facilities amounting to 1.2MWp. This is the first mega-watt class installation in Japan, providing about 1GWh-clean electricity and CO_2 reduction of 450 tons annually. The waterworks is planning to install large PV systems at eight facilities by the end of the 2006 fiscal year. When this is completed, the total installed capacity is expected to be 5.2MWp.

GOVERNMENT SUPPORT

The Japanese government has focused large financial resources on the PV market in order to establish internationally competitive mass production. Comprehensive financial, tax and system

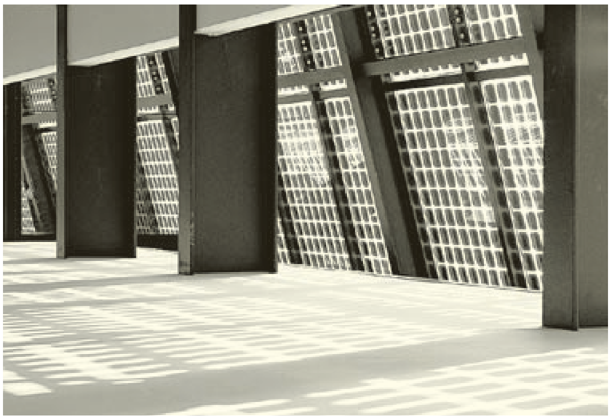
Figure 3.1: Installed PV in Japan by sub-market



Source: IEA- PVPS (except 2005)

support measures are being used to promote solar and other "new energy" (renewable) technologies that are already established but not yet commercially competitive.

Most of this funding - for a mixture of R&D, demonstration programmes and market incentives - has been made available since 1980 through NEDO, the New Energy and Industrial Technology Development Organisation and the New Energy Foundation. Japanese PV budgets grew almost linearly from $20 million in 1980 to $240 million in 2004. But the government ended the subsidy for home application at the end of the 2005 fiscal year, which still accounts for a major part of all installed capac-



ity in Japan. Together with the insufficient RPS policy, this has cast a cloud on the future prospect of the PV market in Japan.

The programmes included in the budget for the 2006 fiscal year are in Table 3.3.

Table 3.3: Japanese PV support programmes

Programme	Budget for 2006 in $ million
R&D for future PV technologies	18
Field test projects on new technologies of PV power generation	107
R&D for accelerating commercialisation of PV systems	7.2
Study of demonstration of improving grid safety for PV system for mass power production and supply	6.3
Community model project for integration of environment and economy (Ministry of Environment)	24
Super Solar Project (Ministry of Environment)	40
Total	**202.5**

While most of the budgets had been cut compared to the previous year, the two programmes covering future PV power generation technologies and improvement of grid safety have seen newly introduced.

Japan's national programmes for renewables during 2004 include:

- ***RPS Law*** *obliges electric utilities to achieve a target for 1.35% of their electricity supply to come from renewable energy sources, including solar, by 2010.*
- *The* ***Regional New Energy Introduction Project*** *aims to accelerate the introduction of new energy (renewable) technologies by supporting regional government projects. Half of system installation costs are subsidised.*
- *The* ***Subsidy Programme for New Energy Developers*** *supports businesses that plan to introduce new energy, including PV.*
- *The programme for development of regional new energy visions helps local government and related bodies to create visions for facilitating promotion of renewable energy at local levels.*

ECONOMICS

Japan has had an aggressive PV R&D programme since the late 1970s, with virtually all funds directed at developing an industry capable of competing in the world market, and with cost reductions that would also serve the domestic market.

In the past five years PV system costs have reduced by another 33%. In the future it is expected that the average price of a residential PV system will fall even further, to below $4,000/kWp. Even so, the cost of PV electricity is still presently more than twice the price of conventional domestic power, which is exceptionally expensive in Japan. If the added value of solar systems in environmental terms were monetised for customers, however, PV would be able to compete much earlier than expected.

PART THREE: THE SOLAR RACE

One other factor is the introduction of premium green pricing for renewable electricity. All ten Japanese regional power utilities introduced a "Green Power Fund" at a monthly rate of $1-4 from October 2000, with the companies matching this amount towards the installation of new renewable plants. Most electric utilities also have net metering systems by which they buy PV electricity from individual customers. As a result of the RPS law, however, some utilities have refused to buy at the same price level when they cannot use credits from the PV electricity put into the grid by individual customers for achieving their respective RPS targets. In these cases, the purchase price has fallen dramatically to 3-5 cents per kWh.

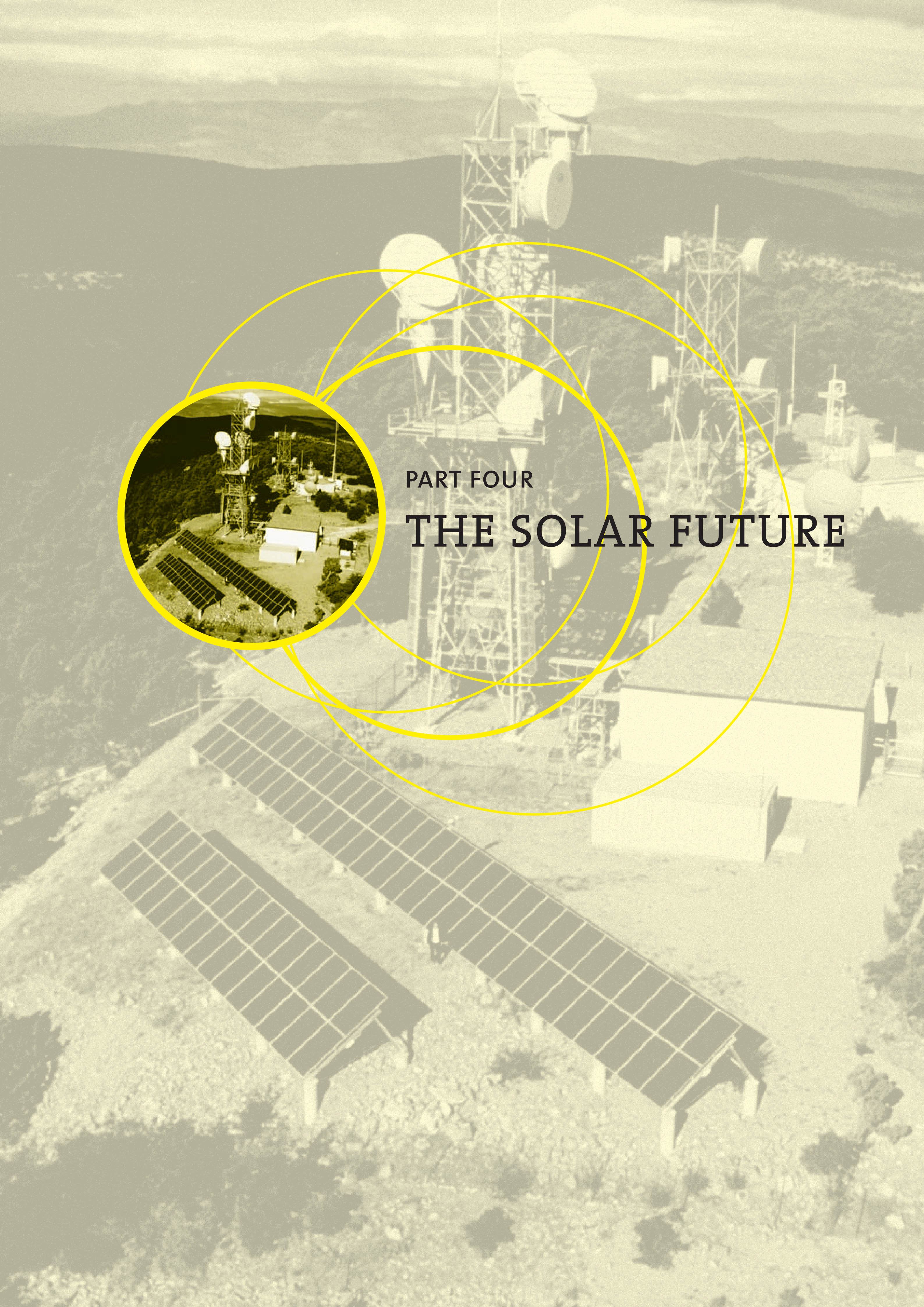
NATIONAL TARGETS

Following the climate change summit at Kyoto in 1997, in 2001 Japan announced an accelerated target to install 4,820MW of PV by 2010. Projections by the Japan Photovoltaic Energy Association (JPEA) show that annual installations could reach 1,230MWp by 2010, with a corresponding market size of $4.5 billion. Looking further ahead, the goal set by JPEA is to increase the annual market to 4,300MWp by 2020, with a total capacity of 28,700MWp installed. For 2030 the goal is to reach an annual market of 10,000MWp, with a cumulative installed capacity of 82,800MWp. By then the PV industry in Japan would have created 300,000 jobs, the PV installation rate will be at 45% for detached houses and the price for a kWp PV system would have fallen below $2,000.

The total future potential for PV power generation in Japan is as much as 173 GW, according to calculations made by the government agency METI in 2000.

Prime power

PV has been installed on a new building at the official residence of the Japanese Prime Minister, a symbol that solar power is central to the country's future energy regime.



PART FOUR

THE SOLAR FUTURE

PART FOUR: THE SOLAR FUTURE

THE GREENPEACE/EPIA "SOLAR GENERATION" SCENARIO

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 energy 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 first 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.

This scenario for 2025, 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:

MARKET GROWTH RATES: For Europe, Japan and the USA, growth rates have been based on market development over the last few years and on targets laid down by some countries for installed PV capacity by 2010. For other countries the market expectations are based on their likely take-off as the technology spreads. The average annual growth rate worldwide up to 2009 is projected to be 35%, and 26% between 2010 and 2015. Between 2016 and 2025 market remains on a high level, however the annual market growth drops to 19% till 2020 and 11% in 2025.

Initial growth is expected to be fastest in the grid-connected sector, by 2010 the growth rates of the emerging off-grid rural sector are expected to overtake the ones from the grid-connected sector, due to a significant reduction in costs and the likelihood of competitive electricity production prices.

ELECTRICITY GENERATION: Figures for the growth in global electricity demand up to 2025, on which comparisons with expected PV development are based, are taken from projections by the International Energy Agency. These show total world demand for power increasing from 13,400 TWh in 2003 to 16,250 TWh in 2010 and 23,250 TWh by 2025. DLR has been asked by Greenpeace International and EREC to conduct a study on global sustainable energy pathways up to 2050. The scenarios are based on the reference scenario from IEA World Energy Outlook (2004). The energy demand is split up in electricity and fuels. A low energy demand scenario has been developed based on the IEA reference scenario: For the year 2025, the energy efficiency scenario estimates a global electricity demand of 16.845 TWh in 2025.

CARBON DIOXIDE SAVINGS: An off-grid solar system which replaces an average 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 electricity production in different countries. The world average figure is 0.6 kg CO_2 per kilowatt-hour. For the whole scenario period it has therefore been assumed that PV installations will save on average 0.6 kg CO_2 per kilowatt-hour.

PROJECTION TO 2040: For the period 2025-2040 a very conservative lifetime of 20 years has been assumed for PV modules. As a result, the capacity installed in the first year of the scenario has been subtracted from the figure for cumulative installed capacity reached after 20 years. This methodology has then been applied to all subsequent years.

The scenario is also divided in two ways; into the four 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. These regions are OECD Europe, OECD Pacific, OECD North America, Latin America, East Asia, South Asia, China, the Middle East, Africa and the Rest of the World.

THE GREENPEACE/EPIA "SOLAR GENERATION" SCENARIO

KEY RESULTS

The findings of the Greenpeace/EPIA "Solar Generation" scenario 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.

1. POWER GENERATION

The Greenpeace/EPIA scenario shows that by 2025 PV systems could be generating approximately 589 terawatt hours of electricity around the world. This means that enough solar power would be produced globally in twenty years' time to satisfy the current electricity needs of nearly 20% of the expanded European Community (EU 25).

The global installed capacity of solar power systems would reach 433 GWp by 2025. About two thirds of this would be in the grid-connected market, mainly in industrialised countries. Assuming that 80% of these systems are installed on residential buildings, and their average size is 3 kWp, each serving the needs of three people, the total number of people by then generating their own electricity from a grid-connected solar system would reach 290 million. In Europe alone there would be roughly 41 million people receiving their supply from grid-connected solar electricity[1].

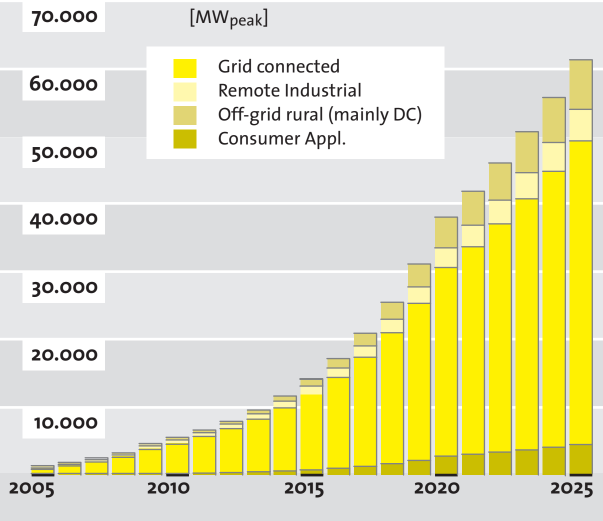
In the non-industrialised world approximately 40 GWp of solar capacity is expected to have been installed by 2020 in the rural electrification sector. Here the assumption is that on average a 100 Wp stand-alone system will cover the basic electricity needs of 3-4 persons per dwelling. Since system sizes are much smaller and the population density greater, this means that **UP TO 950 MILLION PEOPLE IN THE DEVELOPING COUNTRIES WOULD BY THEN BE USING SOLAR ELECTRICITY.** By 2025, more than 1.6 billion people

1. Average European household: 2.5 people with a consumption of 3,800 kWh per year

Table 4.1: The Greenpeace/EPIA "Solar Generation" Scenario

	2025		2020	
Global Solar Electricity Output in 2025:	**589**	**TWh**	**276**	**TWh**
Global electricity demand in 2025 / 2020 (IEA projection)	2,5	%	1,3	%
Global electricity demand in 2025/20 with moderate energy efficiency (Greenpeace International Projection)	3,5	%	1,7	%
Global Solar Electricity Output in 2040:	4890	TWh		
Global electricity demand in 2040 (IEA projection)	16	%		
Global electricity demand in 2040 with moderate energy efficiency (Greenpeace International Projection)	24	%		
Detailed Projections for 2025:				
PV systems capacity	433	GWp	205	GWp
Grid-connected consumers world wide	290	million	135	million
Off-grid consumers	1.6	billion	900	million
Employment potential, full-time jobs world wide	3,2	million	1,9	million
Investment value				
Average annual investment value 2005 - 2025	45,2	billion €	30,9	billion €
Investment value in 2025	102,5	billion €	76,1	billion €
Prices for grid connected PV systems; Reduction down to	2	€ per Wp		
Cumulative carbon savings	2.204	million ton.CO_2	851,5	million ton. CO_2
Annual CO_2 savings	353	million ton.CO_2	165,4	million ton. CO_2

Figure 4.1: Growth in world solar market by application



could get electricity from offgrid photovoltaics systems. 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 from 23.228 TWh in 2025 to 36,500 TWh, **THE SOLAR CONTRIBUTION WOULD EQUAL 16% OF THE WORLD'S ELECTRICITY OUTPUT.** Combined with energy efficiency measures, this share could be reached several years earlier. This would place solar power firmly on the map as an established energy source.

2. EMPLOYMENT

More jobs are created in the installation and servicing of PV systems than in their manufacture. Based on information provided by the industry, it has been assumed that, up to 2010, 20 jobs will be created per MW of capacity during manufacture, decreasing to 10 jobs per MW between 2010 and 2020. About 30 jobs per MW will be created during the process of installation, retailing and providing other local services up to 2010, reducing to 27 jobs per MW between 2010 and 2020.

As far as maintenance is concerned it is assumed that with the more efficient business structures and larger systems in the industrialised world, about one job will be created per installed MW. Since developing world markets will play a more significant role beyond 2010, however, the proportion of maintenance work is assumed to steadily increase up to two jobs per MW by 2020. The result is that by 2025, **AN ESTIMATED 3.2 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.

3. COSTS AND INVESTMENT

The rapid rise in the price of crude oil in previous years and its subsequent knock-on effect on conventional energy costs across the domestic and industrial sectors worldwide, has once again highlighted the urgent need for both industrialised and less developed economies to rebalance their energy mix. This hike in the oil price is not just the result of concerns about security of supply, but also of rapidly rising demand in the emerging economies in Asia, particularly China. Oil production can no longer expand at the same rate as the rise in demand. As such, higher oil prices – and subsequently, higher energy prices in general - are here to stay and world economies will have to adjust to meet this challenge in order to grow.

It is in this climate of runaway energy pricing that those economies that 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 numerous countries having to rapidly reduce their dependence on imported oil and gas. This abrupt transition will be felt in particular in those countries 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 these economies 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.

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. Clearly it is an essential goal for the solar industry to ensure that prices fall dramatically over the coming years and decades. However, there are 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 grid power in industrialised countries.

Tab. 4.2: Projected growth of world solar power market untill 2025

Year	Annual Installed Capacity [MW]	Annual Growth Rate [%]	Estimated Annual Electricity Production [MWh]	Estimated Reduction of COc [COc]	Estimated Jobs
1995	*Market datas from EPIA, all other figures calculated* 79	12,3	122.800	73.680	2.399
1996	89	13,5	211.900	127.140	2.752
1997	126	41,6	338.000	202.800	3.872
1998	153	21,1	464.100	278.460	4.710
1999	201	31,9	665.500	399.300	6.195
2000	259	38,0	341.140	1.017.480	13.665
2001	334	28,9	2.214.220	1.328.532	16.778
2002	439	31,4	2.802.000	1.681.200	22.472
2003	594	35,3	3.582.897	2.149.738	27.949
2004	815	37,0	4.471.497	2.682.898	34.702
2005	1.397		6.479.382	3.887.629	53.683
2006	1.877	35,0	8.754.036	5.252.421	73.974
2007	2.537	35,0	11.841.330	7.104.798	99.695
2008	3.433	35,0	16.035.409	9.621.245	137.635
2009	4.647	35,0	21.738.499	13.043.099	190.179
2010	5.609	26,0	28.746.819	17.248.092	228.714
2011	6.839	26,0	37.444.366	22.466.620	281.747
2012	8.425	26,0	48.344.329	29.006.597	347.162
2013	10.489	26,0	62.135.606	37.281.363	427.878
2014	13.194	26,0	79.746.741	47.848.045	527.524
2015	16.765	26,0	102.433.996	61.460.398	650.629
2016	18.784	19,0	127.944.386	76.766.632	802.853
2017	21.312	19,0	156.955.610	94.173.366	991.289
2018	24.525	19,0	190.369.868	114.221.921	1.224.842
2019	28.666	19,0	229.399.819	137.639.891	1.514.723
2020	34.079	19,0	275.689.801	165.413.881	1.892.736
2021	37.162	11,0	326.360.393	195.816.236	2.083.060
2022	40.743	11,0	382.126.590	229.275.954	2.334.287
2023	44.902	11,0	443.818.149	266.290.890	2.610.636
2024	49.732	11,0	512.400.242	307.440.145	2.914.621
2025	55.343	11,0	588.997.967	353.398.780	3.249.004
Total 2000 till 2025	**433.067**			**2.203.696.207**	

Figure 4.2: Employment in PV related jobs world wide

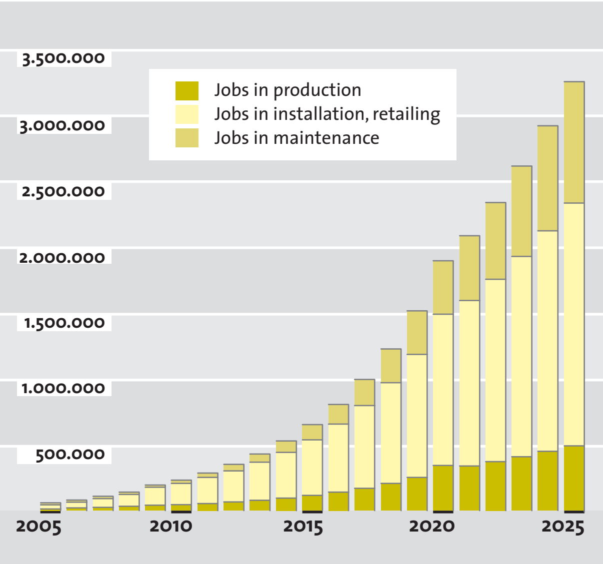
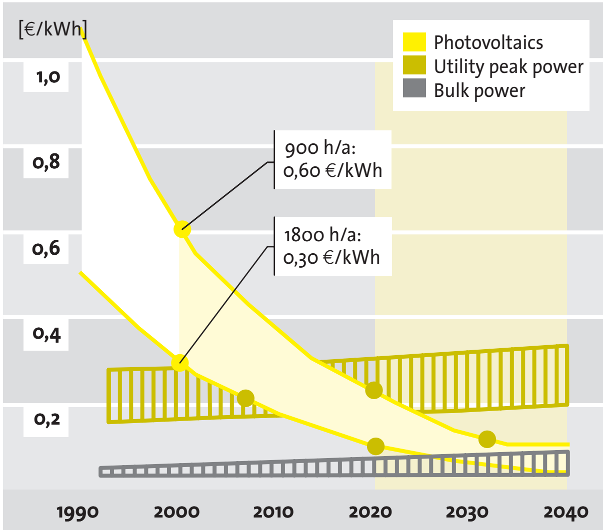


Figure 4.3: PV Competitiveness



Source: RWE SCHOTT Solar GmbH

Table 4.3: Fall in price of PV electricity in selected cities up to 2025

		2005	2010	2015	2020	2025
	kWh/(year*kWp)	[€cents/kWh]	[€cents/kWh]	[€cents/kWh]	[€cents/kWh]	[€cents/kWh]
Berlin - 850 kWh/a	850	0,39	0,31	0,26	0,23	0,21
Paris - 1000 kWh/a	1000	0,33	0,26	0,22	0,19	0,18
Washington - 1200 kWh/a	1200	0,28	0,22	0,19	0,16	0,15
Hongkong - 1300 kWh/a	1300	0,26	0,20	0,17	0,15	0,14
Buenos Aires / Sydney - 1400 kWh/a	1400	0,24	0,19	0,16	0,14	0,13
Bombay - 1400 kWh/a	1400	0,24	0,19	0,16	0,14	0,13
Bangkok - 1600 kWh/a	1600	0,21	0,16	0,14	0,12	0,11
Los Angeles - 1800 kWh/a	1800	0,19	0,15	0,12	0,11	0,10
Dubai - 1800 kWh/a	1800	0,19	0,15	0,12	0,11	0,10

Table 4.4: Value of regional PV market in Million €

Year	OECD-Europe	OECD N. America	OECD-Pacific	Latin America	East Asia	South Asia	China	Middle East	Africa	ROW	Total
2005	4.200	616	1.674	389	293	308	306	64	213	34	8.100
2010	10.983	2.710	5.125	1.103	1.083	979	1.087	346	732	87	24.245
2015	13.401	9.208	11.851	3.388	3.972	3.194	4.753	1.516	2.984	357	54.628
2020	11.361	11670	11.903	7.234	4.475	5.056	21.312	3.937	5.734	1.211	83.898
2025	10.226	15.704	7.695	15.040	5.368	8.497	28.678	8.186	11.921	2.518	113.839

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.

The falling cost of PV cells and modules has been a crucial factor in the recent development of the technology. An indication of the potential for increased efficiency in the production of cells has been given in Part two, together with the likely shift in favour of cheaper thin film technologies.

In this scenario it is projected that the price per Wp for additional production sites will drop to €1.12 by 2010. Between 2010 and 2020 a further price decrease is anticipated. On the basis that the current progress ratio is maintained, an **EX-WORKS PRICE OF €2/WP FOR CRYSTALLINE MODULES WILL BE ACHIEVED BY 2010.**

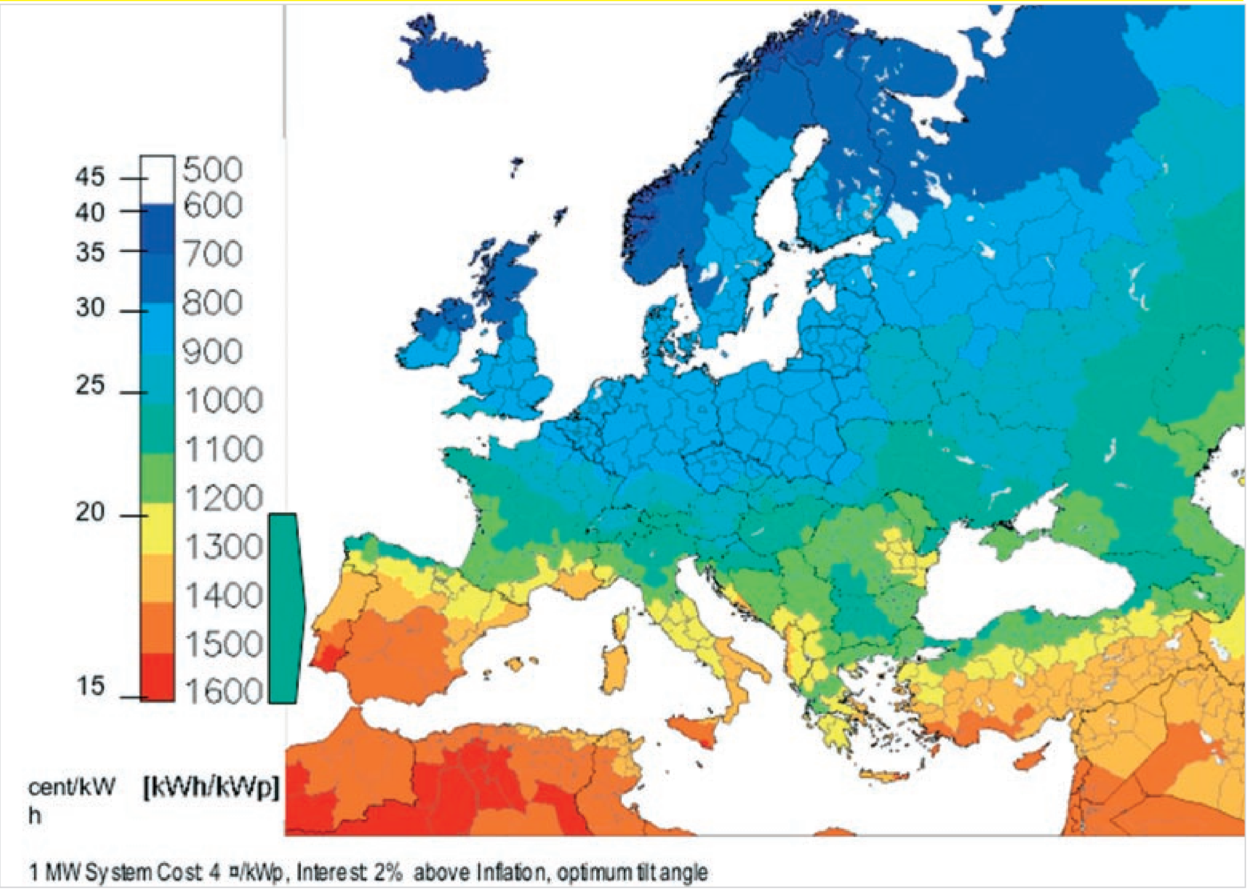
DEVELOPMENT OF SOLAR ELECTRICITY COSTS

The graph "PV Competitiveness" shows the previous and the expected development of solar electricity costs. The falling curves show the reduction of solar electricity costs in the geographical area between central Europe (upper line of the corridor, e.g. Berlin, Germany) and Southern Europe (lower boundary line of the corridor, e.g. Sevilla, Spain). In contrast to the falling costs for solar electricity the prices for conventional electricity will rise. The utility prices for electricity are differentiated into peak power prices (usually applicable at peak demand hours around midday) and bulk power. In southern Europe solar electricity will become price competitive with peak power already before 2010. Areas with less solar irradiation such as central Europe will follow this path in the period up to 2020.

The following map shows the regional solar electricity costs for a PV system price level of 4 €/Wp, which will be feasible within the next few years. This graph underlines that solar electricity at these system costs will be competitive with electricity prices for end users.

In terms of delivered electricity, it is possible to make predictions for the output from grid-connected systems. The results are given for an average consumer in some of the major cities of the world (*see Table 4.1*). These show that by 2020 the cost of solar electricity in the most insolated or sunny regions – the Middle East, Asia , South America and Australasia – will have more than halved to as little as 10-13 € cents/kWh in the best conditions. This would make PV power competitive with typical electricity prices paid by end consumer households.

Figure 4.4: Regional PV-Generation Cost



Source: EC Joint Research Centre, Ispra

Figure 4.6: Global Investment in new PV production facilities

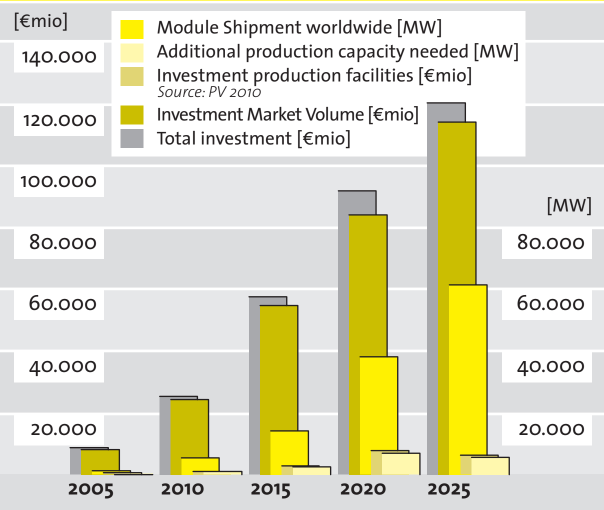
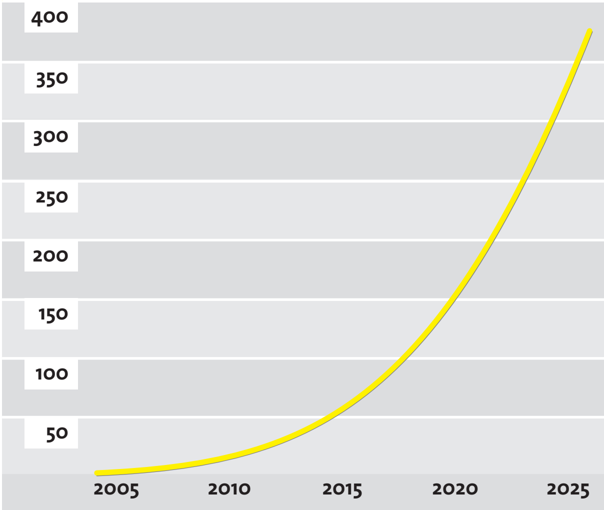


Figure 4.7: Annual global COc savings in millions of tonnes



Of equal importance in relation to falling costs is the level of investment in manufacturing capacity. Here the scenario shows that the global value of the solar power market will have reached €113 billion by the end of the scenario period. Investment in new production facilities will reach €6.2 billion by 2025. The overall market volume for PV systems will increase to €126 billion. Just over €10 billion of that value will be located in Europe, €15.7 billion in OECD North America and €5.4 billion in East Asia.

4. CARBON DIOXIDE REDUCTIONS

A reduction in the levels of carbon dioxide being emitted into the world's atmosphere is the most important environmental benefit from solar power generation. Carbon dioxide is the gas largely responsible for exacerbating the greenhouse effect, leading to the disastrous consequences of global climate change.

As the world's solar electricity production increases, there will be equivalent reductions in the amount of carbon dioxide thrown out into the atmosphere. As already explained, PV systems produce none of the harmful emissions resulting from fossil fuel power generation. Every solar system installed will therefore result in the avoidance of generation from a polluting source.

At the same time, modern solar photovoltaic installations have a very good energy balance. The CO_2 emissions resulting from the manufacture, installation and servicing over the life-cycle of solar generators are "paid back" within the first three to four years of operation for crystalline technology. According to PV manufacturers this will further decrease for thin film technologies energy pay back times of less than one year are realistic.

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 40Wp module, equal to 25 kg CO_2 per kWh. In the consumer applications and remote industrial markets, on the other hand, it is very difficult to identify exact CO_2 savings per kilowatt-hour. As already explained, over the whole scenario period it was therefore estimated that an average of 0.6 kg CO_2 would be saved per kilowatt-hour of output from a solar generator. This approach is quite conservative, so higher CO_2 savings may well be possible.

By 2025 solar PV would also have one other important effect. In environmental terms, it would have reduced annual CO_2 emissions by 353 million tonnes. This reduction is equivalent to the emissions from Australia and New Zealand, or 150 coal-fired power plants. Cumulative CO_2 savings from solar electricity generation between 2005 and 2025 will have reached a level of 2.2 billion tonnes.

EXTERNAL COSTS OF 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 eventual consequences of climate change. There is an 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/tonne CO_2*
- *Medium $20.7 – 52.9/tonne CO_2*
- *High: $160/tonne CO_2*

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.
The assessment above concludes that solar power 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. These external costs must be taken into account when comparing solar systems with other energy sources.

Figure 4.8: World solar power market by region 2005

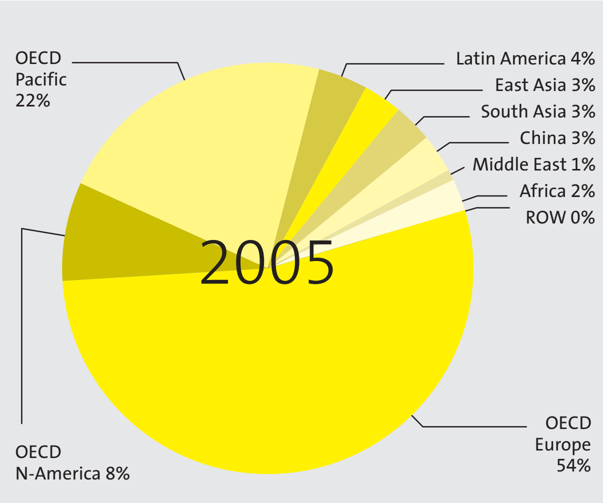


Figure 4.9: World solar power market by region 2010

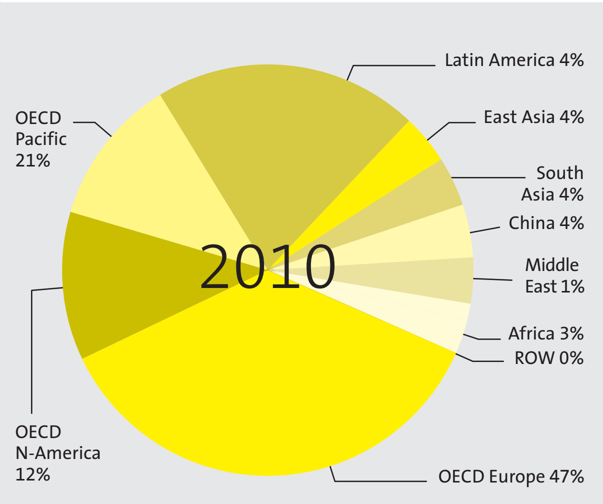
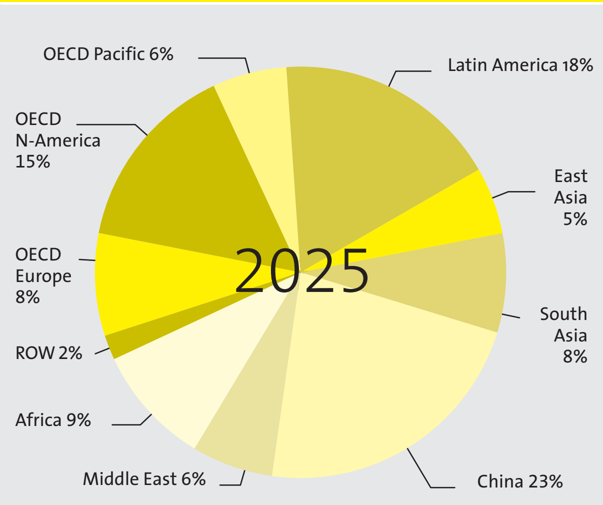


Figure 4.10: World solar power market by region 2025



5. REGIONAL DEVELOPMENT

The development of the PV market is expected to vary from region to region around the world. The overall pattern of the scenario is that while the OECD regions, especially the USA, Japan and Europe, will dominate the global market up to 2010, after that much faster development is expected to take place in other regions, especially South Asia and Africa. By 2025 installed PV capacity in the OECD regions will have fallen to less than half the world total (see *Figures 4.6-4.8*).

The major driving forces behind the future growth of PV capacity in each of the most important regions is described below, together with the conclusions reached in the scenario.

OECD EUROPE

The European Union's current target, part of a broader strategy for renewable energy, is to reach at least 3 GWp of installed PV power by 2010. This scenario demonstrates that this goal can be exceeded, and that a capacity of 5 GWp in Europe by 2010 is possible.

Reasons for this optimism include the fact that the PV market in Germany grew by more than 700% between 2002 and 2005. This demonstrates the impressive growth rates that can be triggered by clearly defined and attractive support mechanisms such as the German "feed-in tariff" offering fixed premium prices for renewable energy output.

PREMIUM FEED-IN TARIFFS

Since the first issue of Solar Generation in 2001 other European countries have also implemented various incentive programmes, mostly based on premium tariffs and in some cases combined with investment subsidies. Spain, Austria, Italy and Luxembourg have all introduced incentive schemes for solar electricity, some more successfully than others. Spain revised its support scheme for solar electricity, which is mainly based on a premium feed-in tariff, and Italy introduced a feed-in tariff for solar electricity in mid 2005. Luxembourg has a combination of feed-in tariff and investment support, resulting in the highest per capita installed PV capacity in the world. In June 2006 Greece followed with a system of premium tariffs for solar electricity.

The situation in Europe differs from Japan, which has experienced a similar solar boom to that in Germany. PV systems in Japan are mainly sold as part of new houses, offering the advantage that the costs can become part of the home mortgage. This system is also possible because the Japanese construction industry is dominated by a very few large companies offering standardised houses with standardised PV systems. By contrast, the construction industry in Germany and other European countries is much more diverse and the houses more customer tailored.

Looking at the growth in different European markets over the past few years it has become evident that premium feed-in tar-

iffs are the most appropriate tool for creating an eventual self-sustaining solar electricity market. The development of a large number of substantial solar electricity markets will be essential for the long-term stability of the European solar electricity market and for lowering the risk attached to today's focus on the German market. A strong demand side in the European PV market is crucial in order to provide the basis for a strong and expanding industry. If an installed capacity of 4.7 GWp by the end of 2010 is to be achieved, it must therefore be a strategic goal to establish a feed-in tariff (full cost rates) for solar electricity at a European Union level.

The EPIA road map

The European Photovoltaic Industry Association (EPIA), representing the majority of the European PV industry, published a new "road map" in 2004. This manifesto outlines the European PV industry's priorities for achieving the objectives of the European Union in relation to installed PV capacities. EPIA has devised a programme of specific actions that the European industry, in collaboration with other key stakeholders from the research, policy, finance, electricity, construction and other sectors, should adopt in order for Europe to capitalise on the global PV market.

The EPIA road map highlights the key obstacles and issues that must be resolved before PV can contribute substantially both to European and global energy supply. It is intended to serve as a guide for the European industry, including research priorities, up to 2010 and beyond, and as a framework for political action to help realise solar electricity's potential to become a major contributor to electricity generation during this century.
(www.epia.org)

CASE STUDY: SOLAR GENERATION IN GERMANY

Germany is currently the key player in the European PV market. As a result of the support provided by the Renewable Energy Law, together with the 100,000 roofs programme (available until mid 2003), the average annual growth rate between 2000 and 2005 was well over 40%. In fact after the 100,000 roofs programme ended in 2003, and the feed-in tariffs was increased – which enabled investor to operate PV installations economically, the market volume tripled between 2003 and 2004 and almost doubled between 2004 and 2005. The annual market in Germany 2005 was approx. 700MW – a market volume which the first issue of Solar Generation in 2001 expected in 2013. According to our first estimate Germany is almost 10 years "ahead of schedule".

Table 4.2 summarises the findings of a case study on Germany in which we looked at the potential increase (at five year intervals) in installed capacity, as well as electricity generation, carbon savings, jobs created and the total value of the PV market. The results show that the electricity output from PV generation could reach 6.5 TWh by 2010. This is equivalent to the output of two centralised coal-fired power plants. By 2015 solar electricity would cover more than 2.4% of Germany's electricity demand and by 2025 more than 5%. The cumulative installed capacity would reach 26,380MW by 2025.

Within the next 20 years the German PV industry could create 80,000 jobs in installation, service and maintenance alone. If all the modules were manufactured in Germany itself this would create up to 12.000 additional jobs. **THIS DOES NOT TAKE INTO ACCOUNT ANY MANUFACTURING ACTIVITIES FOR THE EXPORT OF PV MODULES AND OTHER COMPONENTS. TAKING THIS INTO ACCOUNT THE LEVEL OF 100,000 JOBS IN THE PV INDUSTRY IN GERMANY IS A REALISTIC TARGET.**

GOVERNMENT POLICY AND PROGRAMMES

By itself, the 100,000 roofs programme had a limited success, and the solar boom in Germany only started with the introduction of the Renewable Energy Law in April 2000, which provided premium tariffs for solar electricity. Until mid 2003 the 100,000 roofs programme and the premium tariff system operated in parallel. After the ending of the 100,000 roofs programme, the feed-in tariff was revised at the beginning of 2004 in order to compensate for the fact that low interest loans were no longer available. These new and higher premium feed-in tariffs triggered an even stronger solar electricity boom in Germany. Estimates for new capacity expected to be installed during 2004 range up to 300MWp.

Apart from the attractive feed-in tariff payments there are several factors responsible for the success of this support scheme.

- *The level of the feed-in tariff is high enough to make solar electricity a viable choice for the investor.*
- *The utility is obliged to buy solar electricity at the fixed tariff.*
- *The extra costs for solar electricity are not paid by the state but by all electricity customers, resulting in a very limited additional financial burden (in 2003 the extra cost per household was €12).*
- *The system favours the installation of high quality solar electricity units and the owner has a strong incentive to both maintain the system and maximise energy output for at least 20 years.*

Table 4.5: Solar market in Germany to 2025

	MW	MWh	tCO2	Market Volume in Mio.€	Jobs
2003	139	434.950	260.970	579	4.265
2004	450	884.950	530.970	537	13.639
2005	700	1.584.950	950.970	3.920	21.450
2010	1.200	6.531.943	3.919.166	4.955	37.101
2015	1.293	12.807.404	7.684.443	4.044	50.398
2020	1.359	19.467.624	11.680.575	3.345	76.073
2025	1.428	26.467.583	15.880.550	2.937	79.953
Total 2000 till 2025	**26.380**		**237.059.660**		

- *The tariff is fixed for 20 years, which means security of planning for investors.*
- *At the beginning of each year the feed-in tariff is reduced by 5%, but only for solar electricity systems newly installed that year. For existing systems the tariff remains the same. This feature aims to reflect the expected price decrease in solar electricity and provides an important incentive for the PV industry to reduce its costs.*
- *The support scheme has led to financial payback periods of between 13 and 15 years, leaving the owner with a surplus after 20 years.*

If the *Solar Generation* scenario is to be realised then the feed-in tariffs available under the Renewable Energy Law need to be maintained until 2020 in order to avoid a collapse of the solar PV market. The tariff should decrease annually in relation to progress in reducing production costs. This phased programme should lead to a self-sufficient market and much lower costs for PV installations.

An export market will also become increasingly important for the expanding PV industry in Germany, and will be vital to maintain the market development assumed in this scenario. In March 2001 a new export initiative was launched by German PV manufacturers and dealers, coordinated by the Fraunhofer Institute for Solar Energy Systems. The aim of this initiative is to provide better information and develop new mechanisms to expand the use of off-grid applications.

OECD PACIFIC

Japan offers by far the largest and most developed PV market in this region. The Japanese target is to reach almost 4.8 GWp installed capacity by 2010. Since 2001 the market has grown by 75%, a growth rate based on a strong national PV support programme in which the residential sector plays an important role. Japan also has a clear policy of linking domestic demand to an expanding industrial sector. Alongside this regional leader, a smaller but increasingly important market is expected to develop in Australia. The scenario shows that, with annual growth rates on a substantial but realistic level, the region will eventually become the strongest market in the world.

CASE STUDY: SOLAR GENERATION IN AUSTRALIA

Australia has the potential to develop its own large solar PV industry and become a significant force in the Asia Pacific region. In the 1980s Australia led the world in research and development and installed capacity of PV. Due to a lack of federal or state government support and a meaningful policy framework, this position was lost, but against the background of government action in Japan and Germany to create a PV market, Australia now has the opportunity to rebuild.

Table 4.6: Cumulative installed PV power in Australia by sub-market 31. Dec

Sub-market / application	1992 kWp	1993 kWp	1994 kWp	1995 kWp	1996 kWp	1997 kWp	1998 kWp	1999 kWp	2000 kWp	2001 kWp	2002 kWp	2003 kWp	2003 kWp
off-grid domestic	1,560	2,030	2,600	3,270	4,080	4,860	5,960	6,820	9,110	10,960	12,140	13,590	15,900
off-grid non domestic [1]	5,760	6,865	8,080	9,380	11,520	13,320	15,080	16,360	17,060	19,170	22,740	26,060	29,640
grid connected distributed		5	20	30	80	200	850	1,490	2,390	2,800	3,400	4,630	5,410
grid connected centralized [2]				20	20	320	630	650	650	650	850	1,350	1,350
Total	**7,320**	**8,900**	**10,700**	**12,700**	**15,700**	**18,700**	**22,520**	**25,320**	**29,210**	**33,580**	**39,130**	**45,630**	**52,300**

Notes: 1. Includes replacements. but old modules onsold.
2. Includes diesel grids.

Table 4.7. Solar market in Australia to 2025.

	MW	MWh	tCO2	Market Volume in Mio.€	Jobs
2003	7	83.500	50.100	29	201
2004	7	90.650	54.390	31	221
2005	8	98.515	59.109	50	243
2010	89	327.626	196.576	458	2.726
2015	398	1.519.351	911.611	1.244	12.224
2020	989	5.070.302	3.042.181	2.436	30.509
2025	1.421	11.248.581	6.749.149	2.922	43.937
Total 2000 till 2025	**11.185**		**51.790.516**		

RENEWABLE REMOTE POWER GENERATION PROGRAMME[3]

The Renewable Remote Power Generation programme was established to support a reduction in diesel-based electricity generation by providing up to 50% of the capital costs of off-grid renewable energy installations. Recently it was extended to 'fringe-of-grid'. 2.08 MWp of PV was installed under RRPGP in 2005, bringing the total installed capacity to 5.35 MWp under this programme, of which 0.81 MWp is installed in large utility run diesel grid systems. The latter includes 0.43 MWp of solar concentrating dishes commissioned in the NT, with an additional 0.29 MWp to be commissioned in early 2006. Although it is not PV specific, over 95% of small systems installed under the RRPGP include some PV. The overall programme has funds of around AU$ 205 million allocated to it, of which around AU$ 141 million had been allocated by end 2005. In addition, AU$ 7.5 million has been allocated to industry support activities, including test facilities, standards development, training, feasibility studies and demonstration projects. A specific allocation of AU$ 8 million has been made for the Bushlight programme to assist with the development of industry capability and local understanding of renewable energy systems in small indigenous communities and to install household and community systems.

A total of approximately AU$ 16.7 million was paid towards PV based renewable energy systems during 2005. Around 69% of the systems installed in 2005 were for residential purposes and 31% for agricultural / industrial uses, including water pumping systems. Under the Bushlight programme, 80 communities have been through an energy planning process and 65 PV powered household systems have been installed

PHOTOVOLTAIC REBATE PROGRAMME[4]

Australian Government funded, with administration by the State Governments. The programme commenced in 2000 and is currently funded until 2007. Householders are eligible for a rebate of 4 AU$/W capped at 4,000 AU$ per residential system. Rebates will be reduced in stages to AU$ 3,50/Wp over 2006-2007. Smaller rebates are also paid for extensions to an existing system. Community buildings attract an AU$ 4/Wp rebate but have had a higher cap of AU$ 8,000. This cap will be reduced to AU$ 4,000 from 2006. As part of the Programme, the Australian Government has made available one million Australian dollars to fund projects by residential housing developers and display home builders. A rebate of AU$ 3,50/Wp, reducing to AU$ 3/Wp by end 2007, is available to developers in AU$ 50 000 blocks.

In 2005, 1,042 systems (1.553MWp) were installed, with AU$4.02 million allocated in rebates. This brought the programme total to more than 6,700 systems (8.2 MWp), with rebates of AU$35 million.

MANDATORY RENEWABLE ENERGY TARGET

A national review of the MRET was conducted in 2003 and among its recommendations were the following most relevant to PV:

- *that the 9,500 GWh target for 2010, maintained until 2020, be changed to increase to 20,000 GWh by 2020*
- *that the shortfall charge be indexed to the Consumer Price Index from 2010 onwards*
- *that the deeming time for PV systems with a rating not more than 10 kW be extended from 5 to 15 years*
- *that the eligible threshold for PV generation eligible for deeming be increased from 10 kW to 100 kW*
- *that a review to be undertaken to determine how further consideration can be given to special assistance for the Australian PV industry, either through enhancement of MRET or other measures.*

However, in its 2004 Energy White Paper the government ruled out any increases to the size or duration of the target. The two PV deeming recommendations have been adopted..

SOLAR CITIES[5]

The Australian Government's Solar Cities initiative has stimulated interest in PV, and sustainable energy options more generally, from sectors which have not previously been especially active in the area, such as financial services and local government or, in the case of utilities, which have been active in the past but not been able to pursue useful deployment recently. Consortia were formed to bid for the Solar City funding and comprise a mix of PV companies, banks, local governments, utilities and research groups. The Commonwealth Government is currently evaluating 11 bids from which 4 Solar Cities will be chosen. They will share AU$75 million over 7 years and are expected to include new PV deployment strategies.

THE ROLE OF UTILITIES

The rapid growth in electricity demand, and particularly in peak load demand, is dominating utility planning in Australia at present. Increased air conditioner use is the major contributor to both these trends, but particularly to the increase in peak demand. These developments have an indirect bearing on utility attitudes to PV. At substations where PV can be shown to generate during times of peak demand, there is likely to be utility interest. Nevertheless, PV remains a high cost option and there has been no discussion so far on possible utility incentives for PV installation. At the same time, plans are underway for a national energy regulator to replace the 7 State and Territory regulators. This would encourage more consistent approaches to energy sector regulation in future, and hence to standardisation of procedures, but may not see any direct benefits for PV. Plans are also underway to progressively roll out interval meters across all customer groups. This would allow utilities to introduce time of use tariffs which may place a higher value on daytime power generation. At present PV's daytime generation profile is not rewarded in the market.

THE AUSTRALIAN PV INDUSTRY

Cell production in 2005 was 35.54 MWp and module production 6.72MWp. BP Solar is the major PV manufacturer in Australia and expects to maintain its current production capacity of 50 MW for the immediate future. Origin Energy expects to begin pilot production of its Sliver® cell technology and will consider large scale manufacture in future. In 2005 it released prototype 40, 70 and 140 W modules and received an AU$ 5 million grant from the Commonwealth Government's Renewable Energy Development Initiative to continue its commercialisation trials.

Australia remains a leader in research and development of PV technologies. In 2006, a crystalline thin film technology developed in Australia is to enter commercial production by CSG Solar in Germany and the Sliver® cell technology is to enter pilot production by Origin Energy in Adelaide. Patents for a number of new and improved technologies and production processes continue to be developed and licensed to Australian and international companies. Chinese based PV manufacturer, Suntech Power, which is a joint Chinese - Australian company, continues to improve its production processes in cooperation with Australian researchers. Suntech Power floated on the New York stock exchange in December 2005 and its stock price is currently about twice the listing price. The company has been awarded the contract to supply 130 kW of PV for the Beijing Olympic Stadium. With a weak local market, Australian companies and researchers are likely to continue to look internationally for commercialisation of their technologies.

3/4/5. Australian PV Power Systems Consortium, Task 1, National Survey Report of PV Power Applications in Australia 2005, Muriel Watt, University of NSW, Sydney Australia, May 2006

AUSTRALIAN PV MARKET STATUS

Installations of PV in Australia grew at a steady rate of 15% over last year and totalled 8.3 MWp in 2005. The largest PV market, accounting for 3.4 MWp in 2005, is in off-grid systems for industrial, agricultural and telecommunications applications. Off-grid residential systems comprise the next largest market at 2.9 MWp, followed by grid connected (main grid and diesel grid) residential systems with 1.4 MWp. Australia has many small diesel grid systems in remote towns and 0.5 MWp of PV was connected in centralised systems to the main power stations, in addition to distributed systems connected via individual homes which receive power from diesel grids.

PV module prices remained steady in 2005 at around AU$ 8 per Wp. Prices are largely set on the international market, but are influenced by exchange rates and local delivery costs. System prices vary by location and application but have also remained reasonably steady in 2005. Residential rooftop systems averaged AU$ 12-14 per Wp and stand-alone systems for off grid applications AU$ 19-22 per Wp, although system types and inclusions vary widely.

In the Greenpeace/EPIA scenario, concerted action by industry and government would lead to a strong solar PV industry in Australia, with an increase of the overall installed capacity of approximately 100MWp by 2010. By 2025 the market volume would reach 1,400MWp. About 43,000 jobs could be created in the Australian PV industry. This figure could be even higher if the manufacturers also focused on exports.

In August 2004 the A-stralian PV industry released its own PV Road Map. This includes targets and strategies for the different PV market sectors, and with overall targets for 2010 and 2020 in terms of installed capacity, employment, market value and CO_2 abatement. These differ somewhat from the global Greenpeace/EPIA Scenario, for example where specific Australian assumptions have been taken for the level of carbon reduction.

GOVERNMENT POLICY AND PROGRAMMES3

There are currently two main market development programmes provided by the government for PV in Australia: the Renewable Remote Power Generation Programme (RRPGP) and the Photovoltaic Rebate Programme (PVRP). Some regional authorities provide top-up funds. In addition, the Mandatory Renewable Energy Target (MRET) sets a national requirement for power companies to source an incre°sing proportion of their electricity from renewable energy. The current MRET has not been a particularly strong driver for PV. Nevertheless, increased utility uptake of renewables, and the improved public awareness which accompanies this, provides benefits to all technology groups.

The Jurisdictional Regulators in the states of New South Wales, Victoria and South Australia[1] have released rulings stating that new meters on non-market generators[2] must be able to measure positive and negative flows of electricity separately. However, despite this regulation, net metering may still be legal where all parties agree.

If a system owner wishes to be rewarded for network support and reduced exposure to peak prices, they must be able to measure the gross flow of electricity to the grid at specific times, especially during peak demand. Net metering does not have this capability, and either interval metering or an inverter with separate monitoring or data download is required.

Most retailers currently pay the same tariff for imported and exported electricity, except for Australian Inland Energy, which pays one cent more for export. Some retailers may only pay the wholesale rate for net export. Many of the retailers and Distributed Network Service Providers (DNSPs) are currently reviewing their grid-connect arrangements

1. Independent Pricing and Regulatory Tribunal (IPART) in NSW; Victorian Essential Services Commission (VESC); Essential Services Commission (ESCOSA) of South Australia.
2. Non-market generators must have their entire output purchased directly by the local retailer or by a customer located at the same connection point. Residential-scale renewable energy systems are classified as non-market generators.

CASE STUDY: SOLAR GENERATION IN JAPAN

Japan is currently the world leader in PV applications and the EPIA/Greenpeace scenario expects this position to be maintained for a further 15 years. The success of Japan has been largely attributable to a focus on support for home applications, accounting for over 70% of the total installed capacity. If strengthened policies are put in place, the annual growth rate between 2005 and 2010 is expected to be 30%.

Table 4.5 summarises the findings of the scenario for Japan, showing future prospects for installed capacity, electricity generated, avoided CO_2 emissions, the total value of the PV market and job creation. Installed capacity is projected to reach 3.2 GWp by 2010, with electricity output of about 3.2 TWh. By 2025 it will have exceeded almost 43 TWh, covering 3.5%% of Japan's electricity demand and with an installed capacity of 30 GWp. Over the next 15 years the number of jobs created by the PV industry in installation and maintenance services could be more than 92,000.

GOVERNMENT POLICY AND PROGRAMMES

In order for the ambitious target of 4.82 GWp by 2010 to be realised, appropriate policies must be put in place. The current market growth rate slowed down, and without any additional measure, the target will not be achieved. Rapid expansion of PV installations in Japan has been made possible by a set of efforts by the government, PV manufacturers and utilities, including net metering schemes. Home applications have been playing an important role in the PV market in Japan, representing 90% of installations in Japan last year. The subsidy for home applications, however, ceased at the end of 2005.If the promising home application market is to continue to flourish, either the subsidy for home application should be restarted or a replacement devised.

One significant issue is that consumers currently pay a monthly figure of about $20 to support the programme, and further efforts must be made to reduce the cost of PV systems. Reaching a level of $5,000 per kWp would make the price acceptable to PV installers and could lead to a rapid expansion in home applications.

The Renewable Portfolio Standard enacted by the government in 2003 should be expanded from its current target of 1.35% by 2010 in order to provide an incentive for increased use of solar energy. It should also differentiate between (more expensive) solar generation and other renewable sources such as biomass and wind.

Overall, energy policy in Japan continues to focus on fossil fuels and nuclear energy. More attention needs to be given to the use of renewable energies, including solar, and clearer commitments made by the government for further expansion.

Table 4.8: Solar market in Japan to 2025

	MW	MWh	tCO2	Market Volume in Mio.€	Jobs
2003	223	801.400	480.840	926	6.868
2004	267	1.068.760	641.256	1.030	8.244
2005	291	1.359.760	815.856	1.630	8.997
2010	1.038	4.614.170	2.768.502	4.287	31.914
2015	2.451	14.063.795	8.438.277	7.668	75.670
2020	3.129	28.285.898	16.971.539	7.702	96.835
2025	2.975	43.465.437	26.079.262	6.120	92.261
Total 2000 till 2025	**43.193**		**307.611.647**		

OECD NORTH AMERICA

Growth rates envisaged in this scenario for the North American PV market have been the most moderate in the industrialized world, but much has changed over the past couple of years in the United States. With the adoption of the federal tax credit and state incentives the market is expected to grow substantially over the next decade. By comparison, Canada does not play a significant role as yet, with a total installed capacity of 7MWp and a growth in 2000 of just 1.3MWp.

The US market is increasing significantly, as evidenced by German and Japanese solar companies moving into the US market. The United States also has more sun and higher electric rates in many jurisdictions. As a result solar power will be cost-effective in a number of localities by around 2015 without state subsidies. The US market will need to grow about 20% annually over the next decade to meet the state requirements with annual installed capacity around 2 GWp in 2020. By comparison, the annual solar power markets in OECD Europe and OECD Pacific is expected to grow by 30% per year and exceed 8 GWp by 2020.

CASE STUDY: SOLAR GENERATION IN THE UNITED STATES

If the US government decided to establish a more aggressive long-term support scheme similar to those operating in Germany or Japan, then a different market development would be possible (see *Table 4.6*). This scenario assumes that the US domestic market will develop along the lines of Europe, with an ambitious target for 2,500MWp of cumulative capacity by 2010. To achieve this, strong market growth is required, with the assumption that after 2010 the annual growth rate would be the same as in Europe. This dramatic development would have a serious impact on the world PV market. It would mean that half of the estimated world market volume would be installed in the United States, and the industry would create more than 175,000 jobs.

GOVERNMENT POLICY AND PROGRAMMES

The conclusion of the scenario for US federal and state energy planners is that if Congress extends the federal tax and redoubles its commitment to solar power with expanded research and development funding, and improved interconnection and net metering standards, the market growth could be equal to Japan and Germany. The US PV industry would then be among the world leaders. If the United States continues on its current path, the growth is likely to be about half as large.

Table 4.9: Solar market in the US to 2025

	MW	MWh	tCO_2	Market Volume in Mio.US$	Jobs
2003	63	514.440	296.676	262	1.934
2004	94	690.840	398.196	362	2.883
2005	105	888.840	511.596	588	3.244
2010	603	4.252.724	2.413.120	2.491	18.566
2015	2.240	20.131.573	10.074.184	7.009	68.935
2020	3.608	55.713.157	26.323.334	8.883	111.525
2025	5.811	113.017.654	52.492.752	11.953	179.612
Total 2000 till 2025	**48.618**		**461.923.322**		

SOUTH ASIA

The solar market in South Asia is dominated by India, both on the supply and demand side. A flourishing domestic PV industry has developed in the large Indian market, and there is long-term experience of the technology. The high level of demand for electricity in those areas of the region that are not connected to the grid, coupled with a domestic PV industry and favourable operating conditions, offer excellent opportunities to tap the vast solar electricity potential. The most difficult issue is about how adequate financing can be made available for PV systems to be installed in rural areas where per capita income is very low.

CASE STUDY: SOLAR GENERATION IN INDIA

The only country in Asia with a government department solely devoted to the promotion and support of renewable energy, India's national energy policy is to achieve a 10% share of electricity from renewables by 2012. India offers a 100% subsidy on solar PV systems for remote village electrification. This means that every village which does not have electricity connection can go in for community solar PV systems for which the government has 100% subsidies. For other villages which are electrified, the government offers a 60% subsidy especially for solar pumping systems. For urban solar PV systems, while there is no subsidy offered, the banks and financial institutions offer loans for such systems on a subsidised rate of interest. The rate of interest for such loans is 2% per annum.

The Greenpeace/EPIA scenario is based on an average growth rate between 2000 and 2020 of 35%. By 2025, the Indian PV market would have a market volume of about €4 billion a year. If all the systems installed were manufactured in India itself this would add a further roughly 80,000 jobs to the 108,000 expected to result from work on installation and maintenance.

GOVERNMENT POLICY AND PROGRAMMES

The Indian government needs to continue demonstrating its commitment to mainstream PV by providing incentives to developers and manufacturers of the technology. It should establish a nationwide support scheme with the aim of achieving equal market conditions throughout the country. The national agencies should also look towards attracting foreign investment, either through independent power projects or public sector programmes designed specifically for PV. One further incentive would be the removal of all subsidies for fossil fuel technologies.

EAST ASIA

The East Asian market, currently quite small, is still expected to be one of the key markets over the coming decades. Thailand will be an important player in this region.

CASE STUDY: SOLAR GENERATION IN THAILAND

The Thai government supports the development of renewables through its Energy Conservation Programme. Financial incentives are provided through subsidy schemes, including a 50% grant towards the capital cost of rooftop PV systems during a pilot phase. The National Energy Policy Office and the Department of Energy Development and Promotion are also in the process of preparing a National Renewable Energy Policy that specifies priorities and further support measures. Incentives and an obligation on power producers are expected to deliver an additional 214MW of PV by 2011. A separate project is already underway to provide 120W solar home systems to 300,000 households within the next years. The two measures would together put the nationwide installed capacity at over 250MW by 2011.

Table 4.10: Solar market in India to 2025

	MW	MWh	tCO2	Market Volume in Mio.€	Jobs
2003	11	139.944	83.966	48	344
2004	13	158.693	95.216	54	413
2005	16	181.191	108.715	94	496
2010	180	656.953	394.172	929	5.462
2015	968	4.518.561	2.711.136	3.407	29.734
2020	1.947	15.027.330	9.016.398	4.794	60.108
2025	3.509	34.704.579	20.822.748	7.218	108.384
Total 2000 till 2025	**24.729**	**55.387.251**	**154.446.573**		

Table 4.11: Solar market in Thailand to 2025

	MW	MWh	tCO2	Market Volume in Mio.€	Jobs
2003	3	22.263	13.358	18	104
2004	5	28.844	17.306	24	155
2005	8	38.716	23.229	53	233
2010	82	322.165	193.299	383	2.537
2015	306	1.582.249	949.349	958	9.420
2020	762	5.136.131	3.081.678	1.875	23.488
2025	1.227	11.786.521	7.071.913	2.524	37.920
Total 2000 till 2025	**9.058**	**18.916.888**	**53.267.693**		

Total installed capacity of PV in Thailand is currently about 24.9MW, with approximately 8MW installed during 2005. The two new solar PV programmes could build up a stable and self-supporting network by 2010. The Greenpeace/EPIA scenario is based on a target for 250MW installed capacity by 2010. With a market growth rate of 30% between 2010 and 2015, decreasing to 20% and 10% towards the end of the scenario period, Thailand could become one of the most important PV markets in the East Asia region. Within ten years, this level of market development would create more than 2,000 jobs in installation and maintenance. By 2025 more than 37,000 jobs could be expected in installation and maintenance, with additional potential in manufacture and development.

GOVERNMENT POLICY AND PROGRAMMES

The Thai government should continue to demonstrate its commitment to PV by providing incentives for developers and manufacturers. An essential element of this would be a law similar to India's which removes all institutional, market and policy barriers to the operation of renewable projects, including PV. The Thai authorities should also investigate tapping foreign investment through private or public sector projects. One simple step would be to capitalise on the flourishing overseas tourism industry by ensuring that all resorts and hotels are supplied by solar electricity.

LATIN AMERICA

CASE STUDY: SOLAR GENERATION IN BRAZIL

Presently Brazil's participation in actual the PV world market is very poor, considering the country's potential - which is huge. Side conditions are excellent, high irradiance with low seasonal variations between 1,400 kWh/m_a and 2,200 kWh/m_a and a large amount of possible applications such as substitution of diesel generators in numerous off-grid applications, the obligation of the concessionaries to bring electricity to the whole population until 2008, and general increasing electricity consumption. There are still about 12 million people and 25,000 schools without electricity in Brazil.

GOVERNMENT POLICY AND PROGRAMMES

The largest effort to apply PV was the PRODEEM Programme, which was planned to bring electricity to 6,000 rural locations in Brazil, principally for communal use: schools, health posts, public street lighting, and water pumping. The total installed PV capacity of PRODEEM is 5.2MW, divided into 8,700 systems. These systems have been installed in 26 Brazilian states, principally in the north-eastern semi-arid regions and in the Amazon. It was considered as the largest rural electrification programme in developing countries.

While the planning and purchase phase or PRODEEM was carried out thoroughly, the installation, operation and maintenance phase was a failure due to inadequate locations, incompetent installers, lack of spare batteries, equipment and tools. This gave PV technology a bad reputation in the rural population. After a reconstruction phase, PRODEEM, including PV, was integrated in the large "Luz para todos" (Light/Electricity for all) Programme, which is designed to bring electricity to the entire Brazilian population until 2008.

While there is still no PV feed-in legislation in Brazil, only nine grid connected installations could be identified, mainly set up and operated by research centres, universities and schools. The largest is a 40 kW system at the research centre of Petrobras, the second largest is a 16.5 kW system at CEPEL, the research centre of the national electricity supplier Eletrobras, both located in Rio de Janeiro.

INSTALLED CAPACITY AND ACTUAL MARKET

According to the Ministry of Mines and Energy the present installed PV capacity in Brazil is 9MW. Another study by Professor Zilles from the Electrical Engineering Department at the University of Sao Paulo (USP), considering more international NGO activities, gives a figure of 15MW. Due to the lack of detailed statistics, annual installation rates are not known exactly, but are approximately 3MW for 2005. After the termination of the PRODEEM Programme PV installation has been mainly carried out by NGOs, a couple of projects by Petrobras and Eletrobras, and some private house projects in the kW range.

The Greenpeace/EPIA scenario is based on a target for 150MW installed capacity by 2010. With a average market growth rate of 35% between 2010 and the end of the scenario period, Brazil could become one of the PV market drivers in Latin America. Within ten years, this level of market development would create more than 10,000 jobs in installation and maintenance. By 2025 more than 60,000 jobs could be expected in installation and maintenance, with additional potential in manufacture and development

Table 4.12: Solar market in Brazil to 2025

	MW	MWh	tCO2	Market Volume in Mio.€	Jobs
2003	2	27.672	16.603	10	60
2004	2	31.090	18.654	12	75
2005	3	35.362	21.217	21	94
2010	62	239.881	143.928	319	1.897
2015	332	1.565.175	939.105	1.039	10.205
2020	827	5.718.848	3.431.309	2.035	25.491
2025	2.057	16.054.516	9.632.710	4.232	63.429
Total 2000 till 2025	**11.454**	**23.672.543**	**61.417.048**		

PART FOUR: THE SOLAR FUTURE

In order to achieve the Greenpeace/EPIA scenario the following measures are required:

- *For the private user an effective financing instrument has to be set up. Currently private bank loans are as high as 42% per year: this makes PV investments impossible, even with high grid compensation. A special PV loan for about 8% per year would be needed, such as BNDES for PROINFA.*
- *Import federal taxes are 25% for modules and 20% for cells: these should be reduced by at least 10%.*
- *Import of PV production equipment and raw materials should be tax-free.*
  If all that is fulfilled, a grid-feed compensation of 0.70 R$ (€0.27) per kWh of PV electricity would be viable.
  There are many isolated locations which are designated for the set-up of additional diesel power plants. This should be avoided by applying a CO_2 tax (at international market prices), and cut existing subsidies for remote diesel power supply. PV would be very competitive there.
  A visible showcase project would very helpful for the promotion of solar energy in Brazil and Latin America. A suggestion is the PV power supply for the Island of Fernando de Noronha in the South Atlantic, 300 km away from Natal. This most famous and very beautiful natural sanctuary of Brazil is frequently visited by celebrities and often appears in the media. The island is currently supplied by electricity from several diesel generators and an elderly 75 kW wind generator, and its grid condition is instable. While there is already control of tourist access along with an considerable environmental tax to be charged from every tourist, this instrument may be used to raise PV funds.

CHINA

CASE STUDY: SOLAR GENERATION IN CHINA

As a major fossil fuel generator, China has made a serious commitment towards exploiting its renewable energy resources. On 1st January 2006, the Chinese Renewable Energy Law came into effect, which provides a legal framework for the development of renewable energies in China. The new law includes three mechanisms - supportive tariff, guaranteed grid access and a renewable energy fund. In its following implementing rules, it says that the tariffs for grid-connected solar power projects are decided by the government on the principle of reasonable costs plus reasonable profits. According to the long-term planning proposed by the government, the installed capacity of solar power in China would reach 2,000MW by 2020. By the end of 2005, China had installed a generation capacity of 70MWp, distributed as follows:

Table 4.14: PV in China by Application	Installed capacity by end of 2005
Rural electrification	40MWp
Telecommunications	20MWp
Consumer goods	8MWp
Grid-connected systems	2MWp

In the meanwhile, solar power has played an important role in the rural development of China. Over 60% of the Chinese population lives in rural areas, and 12 million people still had no access to electricity by the end of 2005. The Chinese government introduced the programme "Song Dian Dao Xiang" (sending electricity to villages), which plans to install 100-150MWp of solar power over 2005 to 2010. However, compared to the modesty of Chinese governmental ambition in solar energy, the real performance of Chinese solar industry has been far more encouraging. 2005 witnessed the booming of the Chinese solar PV manufacturer Suntech Power, who sold 1,200MW of its products and successfully launched its IPO on NYSE. Founded in 2001, Suntech has grown into one of the world's top 10 manufacturers within years. The story of Suntech has demonstrated the rapid growth of the Chinese solar PV industry, as well as the huge potential of this market. In the Greenpeace/EPIA scenario, China is expected to produce a growth rate of about 30% over the next decade. This will rise to 45% between 2010 and 2020.

In 2025 the Chinese solar PV market could be the third largest in the world, creating nearly 430,000 jobs in installation alone. The total energy output in 2025 would be 112 TWh, the equivalent of more than 100 coal-fired power plants. This market development needs a strong and long-term support programme.

POLICY RECOMMENDATIONS

Setting bold targets is an important first step for a successful solar energy market. If the target is set too low, like the current target set by the Chinese government for 2020, the required commitment for local manufacture and price reduction will not materialize. On the other hand, supportive policies, especially supportive tariff policies, have to be in place in order to help achieve the ambitious targets. There is still much ambiguity in the current tariff regulations for solar energy projects in China. It is believed that a more easy-to-operate supportive tariff, such as a fixed price feed-in-tariff system similar to those operating in Europe, could give a tremendous further boost to the Chinese domestic market, also for grid-connected PV.

Table 4.13. Solar market in China to 2025.

	MW	MWh	tCO2	Market Volume in Mio.€	Jobs
2003	25	141.000	84.600	130	770
2004	35	183.000	109.800	169	1.075
2005	44	235.500	141.300	306	1.348
2010	211	958.455	575.073	1.088	6.467
2015	1.351	5.365.970	3.219.582	4.753	41.449
2020	8.657	33.616.968	20.170.181	21.313	265.677
2025	13.942	103.380.405	62.028.243	28.679	430.934
Total 2000 till 2025	**86.100**		**347.056.589**		

PART FIVE

THE RIGHT POLICY FOR THE SOLAR GENERATION

PART FIVE: THE RIGHT POLICY FOR THE SOLAR GENERATION

FEED-IN TARIFF: THE DRIVER OF THE SOLAR SUCCESS STORY IN EUROPE

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

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 PV industry. How could this happen? Many different kind of programmes in many countries have been started in the past in order to accelerate the PV markets, but none has been as successful in such a short period of time as the feed-in tariff in Germany. The idea of the feed-in tariff has been adapted in several European states and of course each country adjusted it to its specific needs. The basic idea behind it 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 utilities did not allow the feeding in of solar electricity into their grid and this is still the case in many countries even today. Therefore that right cannot be taken for granted and in most countries the utilities fight this idea forcefully once it comes up.

FEED-IN TARIFF: WHO PAYS FOR IT?

In the past in order to push solar electricity many programmes were financed through a ministry's budget. Obviously this implies the big disadvantage that if state money ran out, the programme could be stopped. Therefore the feed-in tariff model takes a completely different approach.

In Germany in 2006 the utilities pay a premium tariff of €0.51/kWh for solar electricity from newly- installed PV systems. Therefore they have higher costs from the premium tariff. The utilities are authorised to pass this extra cost, spread equally, to all electricity consumers via their usual electricity bill. With this system the feed-in programme works independently from the state economy. The extra cost that each electricity consumer has to pay in order to increase the share of renewable energy in the national electricity portfolio is very small. In Germany the monthly extra costs per household due to the feed-in tariff for solar electricity was less than €0.30. If ALL renewable energy sources are taken into account it was €1.5. In this way every electricity consumer contributes to the restructuring of the national electricity supply structure from a fossil-based one towards a sustainable and independent electricity supply structure.

FEED-IN TARIFF: THE DRIVER OF COST REDUCTION

The costs for solar electricity have been reduced constantly since the technology was introduced to the market. But it is evident that today in most cases solar electricity cannot yet compete with grid electricity generated from fossil fuels. While it is expected that prices for electricity generated from fossil fuels will keep rising constantly, at the same time it is very important to keep a high pace in bringing the costs for solar electricity down. 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 feed-in tariff remains constant over the complete period of 20 years. By this feature of the reduction by 5% each year there is a 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 very easily calculate the return of investment for the PV system. This planning security is an essential element of the success story for the feed-in tariff.

FEED-IN TARIFF: THE DRIVER OF HIGH-QUALITY SOLAR ELECTRICITY SYSTEMS

Many solar electricity programmes are based on an investment subsidy in order to reduce the barrier of high up-front investment for PV systems. The drawback of such an approach is the missing incentive to invest in high-quality solar electricity systems and also to invest in the maintenance of the system during its lifetime. If the customer receives a fixed payment per installed capacity unit, there is no incentive to go for high-quality products that usually mean a higher price.

With the investment subsidy approach there is also little incentive to maintain the system properly over its whole lifetime. Maintenance is linked to a moderate degree of investment, but if the customer received the complete financial incentive upfront, there is no incentive to operate the system at the highest possible level.

With the feed-in tariff the return of investment for the customer is heavily dependent on the performance of the PV system. High performance means high return of investment. The customer gets his return of investment with each kWh that is fed into the grid. Therefore the maximising of the power output of the PV system over its whole lifetime is essential to the customer, and for this reason it is assured that the PV system will be well operated and maintained over its lifetime.

The feed-in tariff is the only system that rewards the generation of solar electricity appropriately and not simply the installation of such a system, which by itself does not have any benefit. Benefits arise only when solar electricity is generated. For this reason one could say that the feed-in tariff is a Solar Generation reward system.

FEED-IN TARIFF: THE DRIVER OF EASIER FINANCING

The up-front cost for solar electricity systems are a clear barrier to a wider market penetration. As explained in the previous paragraph, investment subsidies were implemented in many programmes in order to overcome this barrier. As pointed out 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 to buy a PV system. Of course it took some time until banks became familiar with PV systems and the implications of the feed-in tariff, but in the meantime the financing of PV systems via a bank loan in Germany is no longer a rare and time-consuming thing but very common and straight-forward.

THE FEED-IN TARIFF NEEDS A STRONG CO-DRIVER: SIMPLE AND QUICK ADMINISTRATION

There are countries in Europe with a good feed-in tariff in place but without a viable PV market in existence. How can this happen? The feed-in tariff needs a strong partner in order to be able to unfold its full power and this is a simple and quick approval process from the administration. Even if an excellent feed-in tariff is in place, but the procedures for the approval of the installation of the PV system and for its connection to the grid takes many months, perhaps even more than a year, the number of potential customers will remain very limited. Therefore the customer's effort to deal with administrative and licensing issues needs to be kept at a minimum in order to deter potential customers. A complex and time-consuming administration and licensing process is a clear indication for a electricity market that has not yet made substantial progress on the way to a liberalised energy market.

PART FIVE: THE RIGHT POLICY FOR THE SOLAR GENERATION

PREMIUM FEED-IN TARIFF FOR SOLAR ELECTRICITY

On the support side, customers must not be penalised financially for making a choice to be supplied by solar electricity. In most industrial countries, conventional electricity is heavily subsidised, and the negative environmental impacts of its production are not reflected in the cost to end-users. Changes to this system appear to be some way off and other mechanisms for supporting solar power must meanwhile be promoted.

The German national feed-in tariff offers customers an attractive price for selling their produced electricity to the utility grid. A crucial element of the German feed-in law is the fact that the tariff is set at the point of connection to the grid and this level is guaranteed for 20 years. The fact that the lifetime of this tariff is clearly defined at the outset offers customers planning security that makes the installation of a solar electricity system so attractive. A crucial aspect of the German approach is that the cost of the feed-in tariff is not paid by the government through a subsidy, but is rather financed by a small surcharge. This ensures that such a scheme – once introduced with political support – is less likely to become a political football during times of budget reductions at the government level.

The success of the German feed-in tariff model – which has resulted in the creation of a large number of new jobs in the solar electricity industry – is now being adopted in other countries in Europe. 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 feed-in tariff concept and its low administrative costs means that it is a highly effective and efficient tool for boosting the role of solar electricity in national energy mixes.

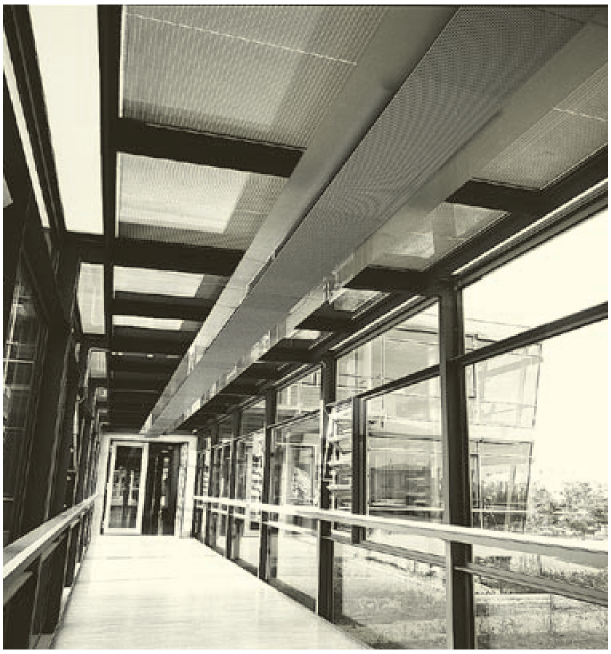
GUARANTEED GRID ACCESS

Given its major advantages for modern society, 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, otherwise there is a risk that they will be squeezed out of the market completely. While instruments such as the European Union's Directive on Renewable Electricity provide for priority access for solar power, this does not guarantee that solar generators will be able to sell the power that they produce. Given the still developing structure of the industry, it is crucial, if we are to achieve a sustainable market in solar electricity in the industrialised world, that such access guarantees are a foregone consideration.

NEW MARKET OPPORTUNITIES

Clearly, just as with other emerging technology markets, decisions are not without their associated financial risks. The clear upward trend of current market developments, however, points to major opportunities for both existing and new players in the solar electricity sector. The expanding list of companies and consortia currently formulating strategies for exploiting the solar market is evidence of this.

For the market really to take off, however, the pioneers of yesterday who have evolved into the market leaders of today must be joined by a widening industrial base so that the whole sector can secure the business successes of tomorrow, the potential for which has been mapped out in this report.



Entry into the solar electricity market is not the preserve of companies only active in the clean energy sector. Many of the leaders in the solar electricity industry were, and still are, leading lights in the “old” energy economy. These global players have taken on board the challenge to integrate a solar electricity business into a traditional energy production and retail structure. The sustained commitment of these companies will be appropriately rewarded if we create the right climate to ensure that the whole solar electricity business sector moves rapidly ahead.

Against this, there are also potential losers in the energy industry. Among these are those companies that have continued to focus solely on conventional energy technologies. With no base or limited expertise available to them in the solar sector, it will become increasingly difficult for these companies to benefit from the expanding photovoltaics market. Its expected growth over the next few decades will rapidly enhance the role that this technology will play in the energy mix. For any organisation missing the boat, the consequences could be similar to those for data processing companies that failed to predict the impact that personal computers would have on every aspect of business and domestic life in the 1980s. Even once mighty blue chip companies such as IBM are still trying to recover from a lack of vision at a critical moment.

GOVERNMENT AND INDUSTRY COMMITMENT

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

At present, the nations of the industrialised world vary greatly in their commitment to solar electricity. While countries such as Germany and Japan, as well as others in Europe, have moved forward from discussion to implementing the necessary support schemes, others have actually cut back their solar electricity programmes. In the United States in particular, this could severely affect the ability of the national solar electricity industry to fulfil its promise as a global exporter providing for sustainable employment at home.

Both industry and governments, however, will have to extend their differing 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, the commitment to the solar electricity sector in many countries needs to be extended. Besides the introduction of net metering and premium tariffs, building regulations need to be adapted 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. New sources of equity and debt financing need to be tapped. Such investment opportunities must attract new entrants to the sector from financial institutions that have been made aware of the potential of the solar electricity business. It is significant, for example, that investment in solar production and supply companies is being taken increasingly seriously by international investment analysts, while the influential Economist magazine has portrayed solar cells as part of a new “micropower” revolution.

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 effect of demystifying the energy process, offering individuals greater control over the provision of their electricity needs. This in itself constitutes a revolution in the energy market.

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