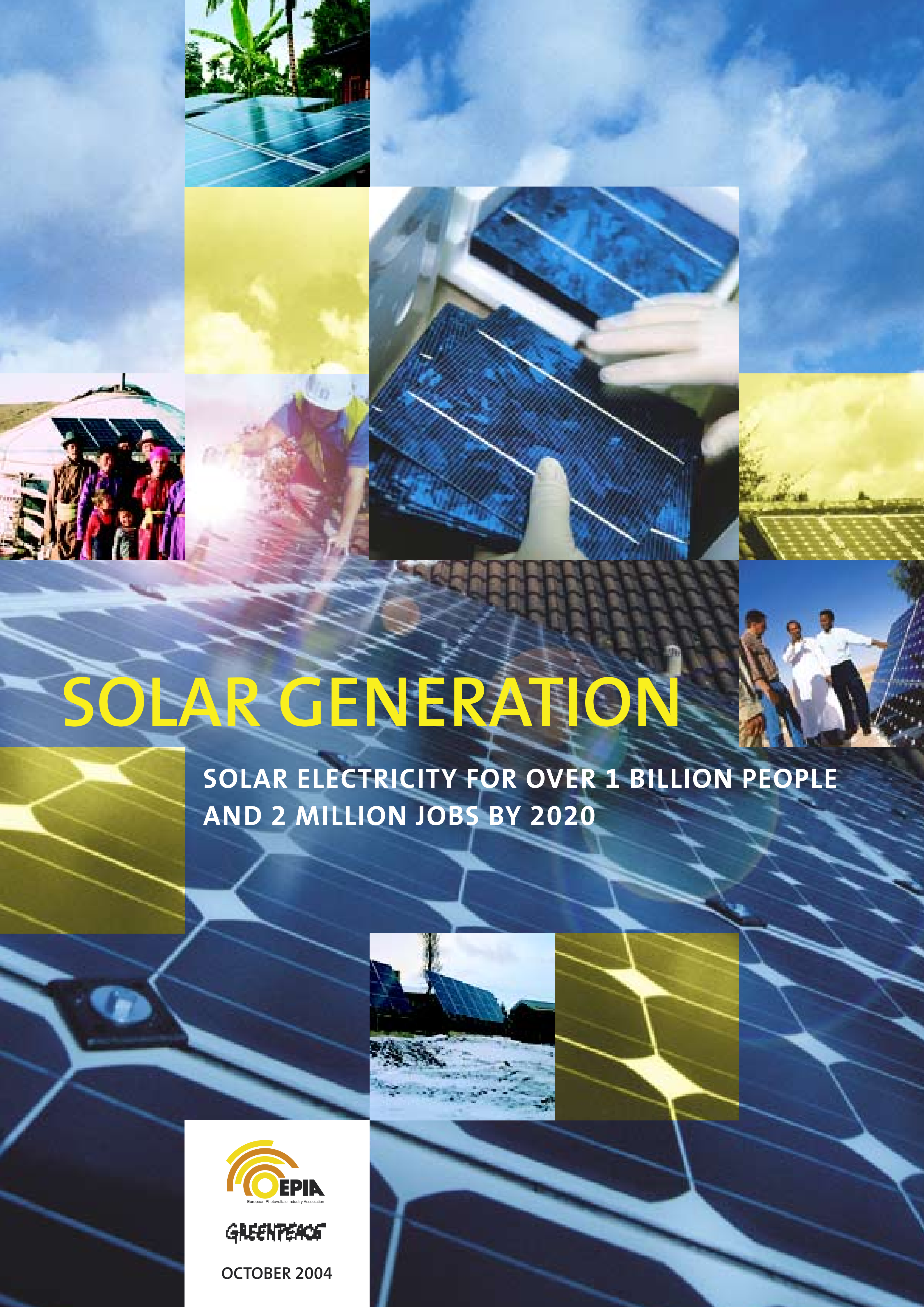

SOLAR GENERATION

SOLAR ELECTRICITY FOR OVER 1 BILLION PEOPLE AND 2 MILLION JOBS BY 2020

EPIA
European Photovoltaic Industry Association

GREENPEACE

OCTOBER 2004

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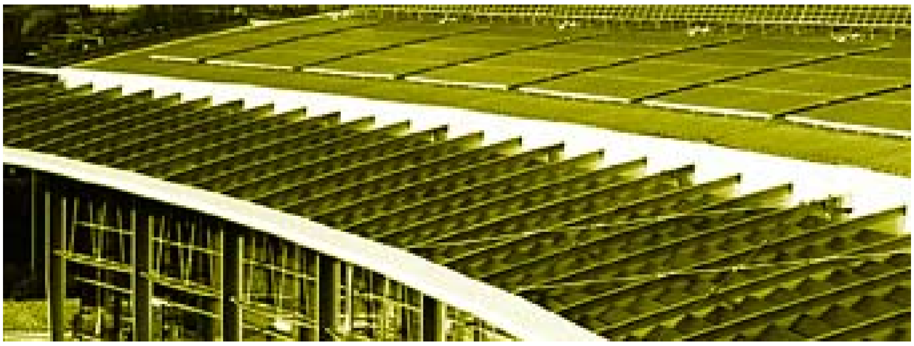
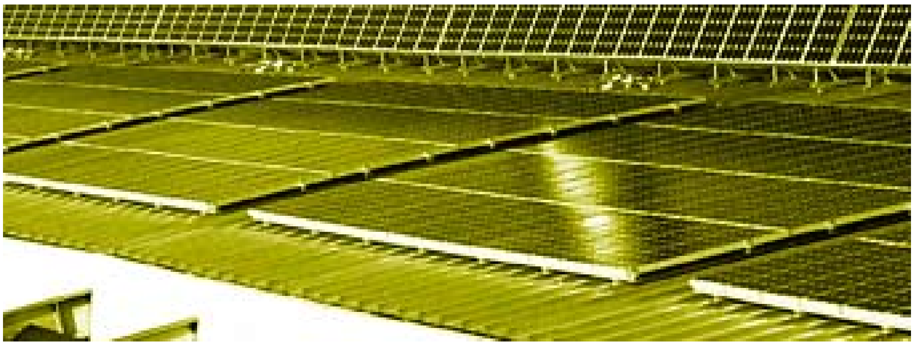


Note: The currency used in this report is mainly the Euro (€) with the US dollar in some sections on non-European countries. It is assumed that, averaged over long timescales, the two currencies have an exchange rate of 1:1.

FOREWORD

The European Commission's Directorate-General for Enterprise sees the photovoltaic industry as a key high-technology sector and has been a major contributor to the creation of a European Photovoltaic Technology Platform. This initiative will help secure the innovation, high investment and strong collaboration between research and industry required by the sector and also help take Europe closer to the Lisbon goal of becoming "the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion".

Climate change is a key challenge that needs to be tackled by competitive eco-technologies. The European Union has played a leading role in defining the Kyoto Protocol. The forthcoming implementation of the emissions trading instrument will pave the way to greater use of renewable sources and to more rational use of energy. Photovoltaic technology, which converts the sun's energy directly into electricity, will contribute to the reduction of emissions in the medium to long term, not only through cleaner projects in Europe, but also in developing countries through the transfer of technology.

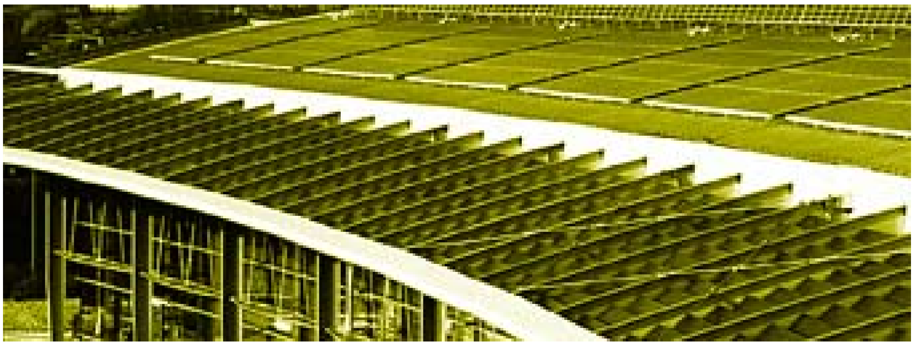
The sun provides more than 10,000 times the energy humanity consumes, meaning that there are few limits to the potential of photovoltaic technologies. For the last five years, the photovoltaic sector has experienced one of the highest growth rates worldwide (over 30% in 2003) and for the 20 next years, the average production growth rate is estimated to be between 27% and 34% annually. Currently the cost of electricity produced using photovoltaic technology is above that for traditional energy sources, but this will fall with technological progress and more efficient production processes.

This EPIA / Greenpeace blueprint traces possible future developments in the photovoltaic sector over the coming decades, foreseeing significant benefits for the environment, but also for society: the photovoltaic sector might employ more than 2 million people by 2020.

These developments will only occur if governments and the public at large welcome this technology. I am convinced this publication will promote this process and look forward to photovoltaic technology starting to play the role it deserves in establishing sustainable development for our benefit and that of future generations.

Günter Verheugen
European Commission Vice President,
Commissioner for Enterprise and Industry

FOREWORD



This report demonstrates that there are no technical, economic or resource barriers to supplying 1.1% of the world's electricity needs from solar power alone by 2020; and this against the challenging backdrop of a projected near doubling of electricity demand by that date. Solar energy is a success story. It already supplies electricity to several hundred thousand people, provides employment for over 10,000 people and generates business worth more than € 3 billion annually

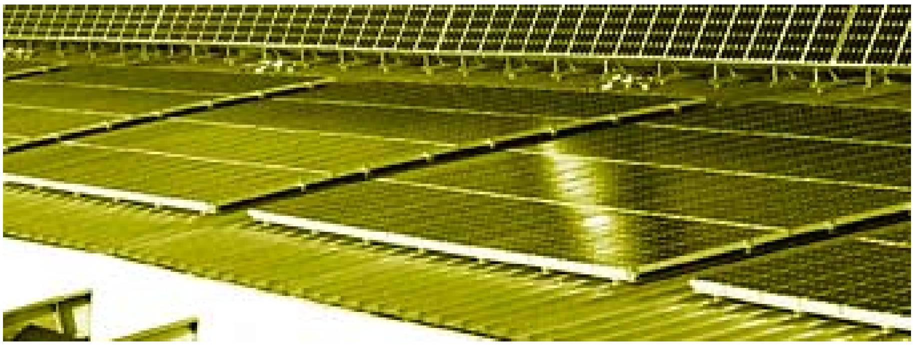
In the future, the pace of change and progress could be even more rapid as the solar industry unlocks its hidden promise.

By the end of 2003 more than 2,400 Megawatts (MW) of solar photovoltaic power had been installed world wide, generating enough electricity to power more than 700,000 households with an average European consumption. As outlined in the opening chapters, the success of the industry to date has been largely created by the efforts of just three countries - Japan, Germany and the USA. It is obvious that if other countries matched these efforts, the impact would be far greater. This underlines the fact that today's technology is merely the tip of the iceberg, and a huge potential remains untapped. Solar power is capable of continuing its successful history over the next two decades if a positive political and regulatory framework is implemented, one that removes the obstacles and market distortions that currently constrain the industry's real 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. The underlying advantage of solar energy is that the fuel is free, abundant and inexhaustible. The total amount of energy from the sun that reaches the earth's surface every year is enough to provide for annual global energy consumption 10,000 times over. Yet these benefits remain largely untapped; most energy decisions taken today overlook solar power as a modular technology which can be rapidly deployed to generate electricity close to the point of consumption. Phasing in solar photovoltaics therefore requires a shift from centralised to decentralised power production, allowing far greater control to individual consumers.

There is now a solid international consensus on the threat of dangerous climate change and that business-as-usual in the energy sector is not an option any more; the world must move into a clean energy economy. The rapidly increasing demand for fossil fuels has already in 2004 propelled the price of crude oil above US$ 50 per barrel for the first time, and has demonstrated that production of "cheap" fossil fuels can no longer grow as fast as demand. Economies that have not prepared themselves for diversification of their energy mix will particularly be affected by these developments in world oil markets. Solar power is a prime choice in developing an affordable, feasible, global power source that is able to substitute for fossil fuels in all climate zones around the world.

The European Photovoltaic Industry Association (EPIA) and Greenpeace have produced this new edition of Solar Generation in order to update our understanding of the contribution that solar power can make to the world's energy supply. The report is a practical blueprint to show that



solar power is capable of supplying electricity to more than 1 billion people within two decades, even if we nearly double our overall electricity use in that time.

This clear industrial and political commitment to the expansion of the PV industry implies that the current surge of activity in the solar electricity sector represents merely a foretaste of the massive transformation and expansion that this sector will bear witness to in the coming decades.

This joint initiative adopted the title "Solar Generation" because it aims to define the role that solar electricity will play in the lives of a global population born today as it develops into a major energy consumption group and starts to enter the job market. The aim has been to examine how solar electricity will be perceived from both a consumer and business point of view within the time scale of a generation. The report highlights the triple benefits which solar energy offers the world - for the environment, for industry and for economic and social development.

The international conference "Renewables 2004" held in June 2004 in Bonn was a small but important step towards an expansion of renewable energies world wide, responding to the call of the Johannesburg summit to increase the share of renewable energy and to keep up the momentum generated by the Johannesburg Renewable Energy Coalition. The European Union has played an important role in this process, following the recommendation of a preparatory regional conference to Renewables 2004 held in Berlin in January 2004 to:

"...urge EU institutions to start a political process of setting ambitious, time bound targets for increasing the share of renewable energy in final energy consumption addressing the medium (2020) and long term time frames in due time to the Renewables 2004 in Bonn. A target value of at least 20% of gross inland energy consumption by 2020 for the EU is achievable."

This number could be even higher if coupled with stronger energy efficiency policies. Targets for renewable energy act as a powerful catalyst for governments to develop the necessary framework conditions for investments in renewable energy technologies. A powerful example is the EU Directive on the Promotion of Electricity from Renewable Energy Sources, which sets national indicative targets for all EU Member States. The targets have initiated political actions throughout the entire European Union to put in place framework conditions for renewable energies. Targets are an important first step in developing the clean energy sources of tomorrow that will contribute substantially to climate protection, but they must be followed by concrete political action.

Reports are a useful guide, but it is people who change the world by their actions. We encourage politicians and policymakers, global citizens, energy officials, companies, investors and other interested parties to support solar power by taking concrete steps which will help ensure that more than a billion people will get electricity from the sun, harnessing the full potential of solar power for our common good.

October 2004

EPIA

Michel Viaud
Secretary-General
European Photovoltaic Industry Association (EPIA)

Greenpeace

Sven Teske
Renewables Director
Greenpeace International

EXECUTIVE SUMMARY

GLOBAL STATUS OF SOLAR PHOTOVOLTAICS

The solar electricity market is booming. In the year 2003 the cumulative installed capacity of solar photovoltaic (PV) systems around the world passed the landmark figure of 2,400 MWp. 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 it is now worth more than an annual € 3 billion.

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

Since the first edition 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 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 clear commercial and political commitment to the expansion of the PV industry means that the current surge of activity in the solar electricity sector represents merely a foretaste of the massive transformation and expansion expected to occur over the coming decades. The target: realisation of a common goal of substantially increasing the penetration of solar electricity into the global energy mix 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 audience as possible the message that solar electricity will bring socio-economic, industrial and environmental benefits to regions which proactively encourage its uptake.

SOLAR GENERATION: A PROJECTION TO 2020

Numerous analyses about the potential market development of solar photovoltaics have been published in the past. The aim here has been to compile a detailed quantitative knowledge base, coupled with clearly defined and realistic assumptions from which extrapolations could be made on the likely development of the solar electricity market up to 2020 and beyond. The results which have emerged from this extensive analysis point to a technology that will make a major impact on the everyday adult lives of the population born today.

Clearly, this transformation will not happen by itself. It will require the far reaching commitment of both 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 those lessons and adapt and deploy the corresponding catalysts on a global level if solar electricity is to play a major role in the lives of the next generation.

SOLAR GENERATION: METHODOLOGY AND ASSUMPTIONS

Taking its lead from success stories like those in Japan and Germany, this EPIA/Greenpeace report looks forward to what solar power could achieve - given the right market conditions and an anticipated fall in costs - over the first 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 would be created and the crucial effect which an increased input from solar electricity will have on greenhouse gas emissions.

This scenario for the year 2020, 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: The average annual growth rate of the worldwide PV market up to 2009 is projected to be 27%, then rising to 34% between 2010 and 2020. Although initial growth is expected to be fastest in the grid-connected sector, by 2010 the off-grid sector will play a steadily increasing role.

Electricity generation: Figures for the growth in global electricity demand up to 2020 (on which comparisons with expected PV development are based) are taken from projections by the International Energy Agency. These show total world power demand increasing to 25,578 Terawatt hours (TWh) by 2020.

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 2020-2040 a moderate annual growth rate of 15% has been assumed, as well as a very conservative lifetime of 25 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:

Global Solar Electricity Output in 2020: 282 TWh
= 10% of EU-25 electricity demand in 2003
= 1.1% of global electricity demand

Global Solar Electricity Output in 2040: 7442 TWh
= 21% of global electricity demand

Detailed Projections for 2020:	
PV systems capacity	205 GWp
Grid-connected consumers	93 million world wide[1] 31 million in Europe
Off-grid consumers	950 million world wide[2]
Employment potential	2.25 million full-time jobs world wide
Investment value	€ 62 billion per annum
Prices for grid connected PV systems	Reduction to € 2 per Wp
Cumulative carbon savings	730 million tonnes of CO_2

1 Calculation basis: 2.5 persons per household, with an annual consumption of 3,800 kWh
2 Calculation basis: A 100 W solar system will cover the basic energy needs of 3-4 people

SOLAR GENERATION: PV'S CONTRIBUTION TO GLOBAL ELECTRICITY SUPPLY

The EPIA/Greenpeace scenario shows that by the year 2020, PV systems could be generating approximately 282 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 10% of the entire EU-25 (2003 figure). Put another way, this would represent the annual output from 76 coal-fired power plants.

Global installed capacity of solar power systems would reach 205 GWp by 2020. About half 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 93 million. In Europe alone there would be roughly 31 million people receiving their supply from solar electricity generation.

Although the key markets are located now mainly in the industrialised world, a global shift will result in a significant share - 30 GWp - being taken by the developing world in 2020.

EXECUTIVE SUMMARY

Since system sizes are much smaller 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 major breakthrough for the technology from its present emerging status.

By 2040, the penetration of solar generation would be even greater. Assuming that overall global power consumption had by then increased from 25,578 to 36,000 TWh, the solar contribution would equal 21% of the world's electricity output. This would place solar power firmly on the map as an established energy source.

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

For the solar production industry, global annual shipments of PV modules will rise from 750 MWp in 2003 to more than 48,000 MWp in 2020. This represents an increase by a factor of 64.

For the job seekers of the 2020 generation, this would represent a major contribution towards their employment prospects. On the assumption that more jobs are created in the installation and servicing of PV systems than in their manufacture, the result is that by 2020, more than 2.25 million full time jobs would have been created by the development of solar power around the world. The majority of those would be in installation and marketing.

By 2020 solar PV would also have had one other important effect. In environmental terms, it would have reduced annual CO_2 emissions by 169 million tonnes. This reduction is equivalent to the emissions from all 45 million cars currently operating in Germany, or 76 coal-fired power plants. Cumulative CO_2 savings from solar electricity generation between 2003 and 2020 will have reached a level of more than 730 million tonnes.

POLICY RECOMMENDATIONS

In order to supply up to a billion people with solar electricity by the year 2020, and go on to achieve a global electricity share of 21% 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.

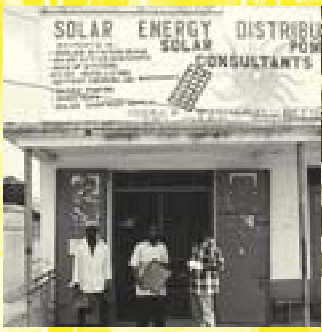
A number of key political actions are required:

- *Firstly, an annual world PV market growth of 3.7 GWp+ 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, a variety of legally enforced mechanisms must be implemented which 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

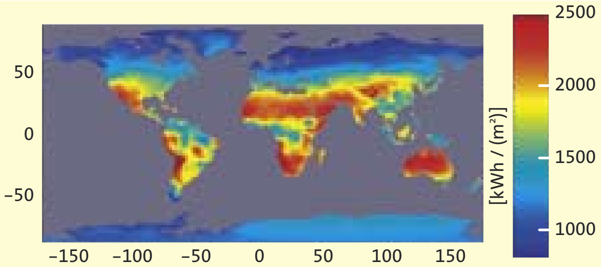


PART ONE: SOLAR BASICS

THE SOLAR POTENTIAL

There is more than sufficient solar radiation available around the world to satisfy a vastly increased demand for solar power systems. The proportion of the sun's rays which 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.

Figure 1.1: Global variations in irradiation



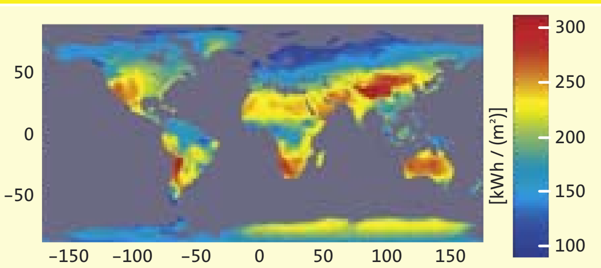
Source: Gregor Czisch, ISET, Kassel, Germany

The statistical information base for the solar energy resource is equally 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.

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, for example, compared with 1,800 kWh in the Middle East.

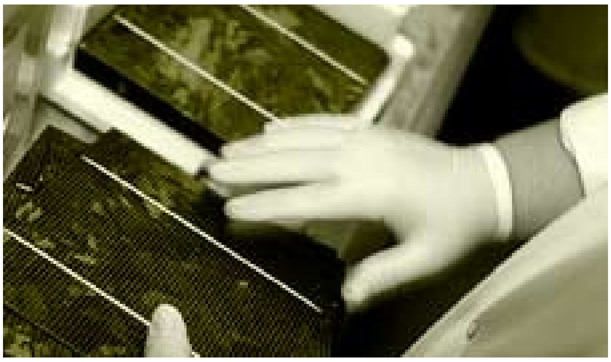
Figure 1.2 shows the estimated potential energy output from solar PV generators in different parts of the world. The calculation used here takes into account the average efficiency of modules and converters as well as the correct angle to the sun required at different latitudes.

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 the market segment 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 about the same as today's contribution from hydro power.



WHAT IS PHOTOVOLTAIC ENERGY?

The word "photovoltaic" is a marriage of two words - "photo", meaning light, and "voltaic", meaning electricity. So photovoltaic technology, the scientific term used to describe solar energy, involves the generation of electricity from light.

The secret to this process is the use of a semi-conductor material which can be adapted to release electrons, the negatively charged particles which 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 does not therefore need bright sunlight in order to operate. It also generates electricity on cloudy days, with its energy output proportionate to the density of the clouds. Due to the reflection of sunlight, days with only a few clouds can even result in higher energy yields than days with a completely blue sky.

Solar PV is quite different from a solar thermal system, 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*
- *No moving parts to wear out or break down*
- *Minimal maintenance required to keep the system running*
- *Modular systems can be quickly installed anywhere*
- *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, the modules which bring together large numbers of cells into a unit, and, in some situations, the inverters used to convert the electricity generated into a form suitable for everyday use.

PV Cells and Modules

PV cells are generally made either from **crystalline silicon**, sliced from ingots or castings or from grown ribbons, or **thin film**, deposited in thin layers on a low cost backing. The majority of module production (89% in 2003) 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 by far larger share of the PV market in the future. This technology offers several advantages such as low material consumption, low weight and a smooth visual appearance.

Crystalline silicon

Crystalline silicon is still the mainstay of most power modules. Although in some technical parameters 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, but production cells are currently averaging 13-17% efficiency. The theoretical limit for crystalline modules approaches 30%.

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 plastic. This results in lower production costs compared to the more material intensive crystalline technology. This price advantage is counter balanced at the moment, however, by substantially lower efficiency rates and less experience of the modules' lifetime performance.

Three types of thin film modules are commercially available at the moment. These are manufactured from amorphous silicon (a-Si), copper indium diselenide (CIS, CIGS) and cadmium telluride (CdTe). All of these have active layers in the thickness range of less than a few microns. This 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. At approximately 6% in 2003, the market share of thin film technology is still fairly low, but can be expected to increase in the future.

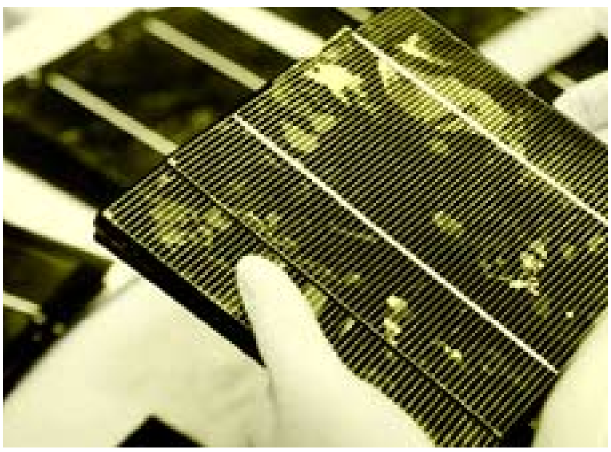
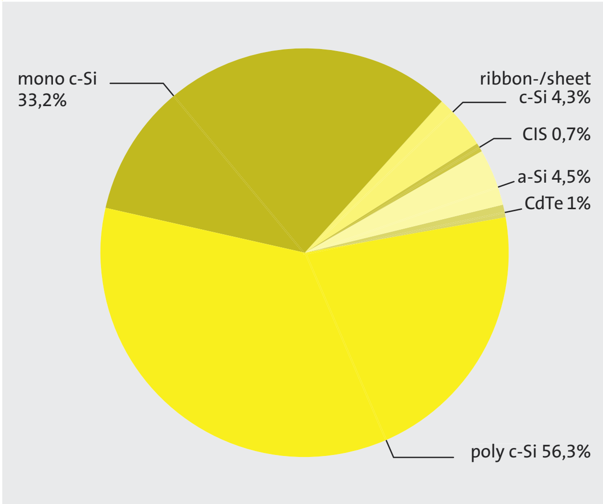


Figure 1.3: Market shares of different cell technologies sold in 2003 (installed capacity)



Amongst 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 2003).

Multicrystalline thin film on glass (CSG) is a promising thin film technology under development, but not yet available on a commercial scale. Microcrystalline technology, in particular the combination of amorphous silicon and microcrystalline silicon (a-Si/µ-Si) is another approach with encouraging results. The efficiency world record for cells with this technology is currently 14.7%, while modules are already commercially available with an efficiency of 10% stabilized. The aim is to increase this level to 12% in 2005.

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.

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. When the first edition of Solar Generation was published in 2001, the development of spheral cells was not even at a stage that allowed a detailed prediction of its commercial availability.

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 their performance for 20-25 years.

When a PV installation is described as having a capacity of 3 kWp(eak), this refers to the output of the system under standard testing conditions (STC), allowing comparison 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 efficiencies

Type	Typical module efficiency (%)
Monocrystalline silicon [mono c-Si]	12-15
Multicrystalline silicon [multi c-Si]	11-14
Amorphous silicon [a-Si]	5-7
Cadmium telluride [CdTe]	6-7.5
CIS	9-9.5
a-Si/μ-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) which is compatible with the local electricity distribution network. This is essential for grid-connected PV systems. Inverters are offered in a wide range of power classes, from a few hundred Watts through the most frequently used range of several kWp (3-6 kWp) up to central inverters for large scale systems with 100 kWp and above.

Components for Stand-alone PV Systems

Stand-alone (off-grid) PV systems contain a **battery**, still today frequently of the lead acid type, in order to store the energy for future use. New high quality batteries designed especially for solar applications, with life times of up to 15 years, are now available. However the lifetime of the battery strongly depends on the battery management and the user behaviour. The battery is connected to the PV array via a **charge controller**. The charge controller protects the battery from over charge or discharge, 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

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, which is considerably higher that the usual tariff paid by the customer to the utility, 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.

Grid Support

A system can be connected to the local electricity network as well as a back-up battery. Any excess solar electricity produced after the battery has been charged is then sold to the network. Ideal for use in areas of unreliable power supply.

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.

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 costed, it is clear that the overall economics of PV generation would be dramatically improved in numerous applications, even in some grid-connection situations.

Climate Change and Fuel Choices

Carbon dioxide is responsible for more than 50% of the man-made greenhouse effect, making it the most important contributor to climate change. It is produced mainly by the burning of fossil fuels. Natural gas is the most environmentally sound of the fossil fuels because it produces roughly half the quantity of carbon dioxide and less of other polluting gases than coal. 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 already apparent today include:

- *The proportion of CO_2 in the atmosphere has risen by about one third since industrialisation began.*
- *The number of natural disasters has trebled since the 1960s. According to insurance company Munich Re the resulting economic damage has increased by a factor of nine.*
- *The eight warmest years over the last 130 were recorded during the past 11.*
- *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.*
- *According to a WHO study, as many as 160,000 people are already 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 have still 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 only a quarter of the fossil energy reserves which can be developed commercially today ought to be allowed to be burned if ecosystems are not to go beyond the point at which they are able to adapt.

Space-saving installation

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

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

Improving the electricity network

For power companies and their customers, PV has the advantage of providing relatively quick and modular deployment. This can offset investment in major new plant and help to strengthen the electricity network, particularly at the end of the distribution line. Since power is generated close to the point of use, such distributed generators reduce transmission losses, can improve service reliability for customers and help limit maximum 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 paragraph "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 paragraph "The Climate Change Imperative").

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.

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.

The 1997 Kyoto Protocol, now ratified by 124 nations, has meanwhile committed the world's industrialised countries to reducing their emissions of greenhouse gases by an average of 5% from their 1990 level. Kyoto will not come into force unless it is ratified by countries responsible for 55% of 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, however, the Russian government announced it would ratify the Kyoto Protocol, bringing it into force in early 2005.

Other climate change prompted commitments include:

*The **European Union** has set a target to double the proportion of energy in the 15 member states (before the latest enlargement) provided from renewable sources. The aim is for 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". Other countries around the world have similar targets for large numbers of grid-integrated PV systems (see Part Three: The Solar Race).*

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

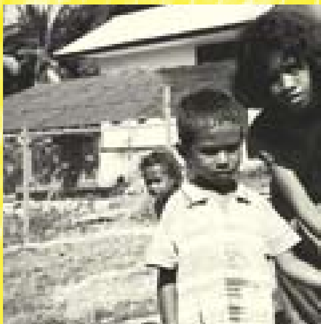
Energy payback

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 3 to 4 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 2003 the cumulative installed capacity of all PV systems around the world had reached the landmark figure of 2,400 MWp. This compares with a figure of 1,200 MWp at the end of 2000, reflecting a doubling of the total installed capacity in just three 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 industry that sales are now worth an annual € 3 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

In the year 2003 this sector accounted for roughly 35 MWp, about 5% of global annual production. 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. In 2004 Siemens announced the development of an organic solar cell with 5% efficiency.

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 BIPV (Building Integrated PV), with the average capacity of domestic systems in Germany now above 5 kWp. For comparison, 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 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 1,100 MWp. 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 and with the advantage of a 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 70% by 2003.

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 Part Three: 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.

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.

Among the uses made of solar electricity in off grid situations are for domestic lighting, solar lanterns, TV sets, water pumping, refrigerators and providing lighting for shops, health centres or small market places.

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 major 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 to link 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.

PV Around the World

- *A 1.1 MWp solar electricity system was installed on the roofs of the new trade fair building in Munich, Germany in 2002. Together with an existing 1 MWp system this now represents the largest roof mounted solar electricity system in the world, providing electricity for more than 700 households.*
- *Senegal's countryside is being transformed by projects run by the Senegalese Agency for Rural Electrification, a government department formed in 2001. With workers busily putting up solar panels and poles to connect them to the grid, the project aims to raise the percentage of Senegal's 324 rural counties with electricity from nine to 15% by 2005, and to at least 60% within 20 years.*
- *If the home team isn't winning at the new Stade de Suisse in Berne, Switzerland there will at least be a tour of the stadium's PV system to take the fans' minds off the game. On the roof, BKW FMB Energy is building a 1.3 MW solar plant and energy platform to power the building and its surrounding complex.*
- *A solar pergola with a capacity of 444 kWp was installed in Barcelona, Spain to mark the 2004 World Forum of Cultures. This unique landmark shows the added value which solar electricity technology can contribute to an urban environment.*
- *A 400 kWp ground based systems using thin film modules was connected to the grid in Waltenhofen near Munich, Germany in December 2003. A landmark in innovation for the solar electricity market, only 6 months later a 1 MWp ground based system with the same technology was installed in Buttenwiesen, southern Germany, demonstrating the rapid development in this market segment.*
- *A 5 MW PV array with 33,500 modules was opened in September 2004 on a former dump site for lignite coal ash in Espenhain, Germany. The output will be fed into the grid to serve 1,800 homes, and will displace the emission of 3,700 tonnes of CO_2 each year*

PART TWO: THE SOLAR POWER MARKET

SUPPLY SIDE MANUFACTURE

Solar Cell and Module Production

The manufacture of solar cells and modules is presently concentrated in three key areas - Europe, Japan and the United States. Japan leads the world, with solar cell shipments reaching more than 365 MWp in 2003, a 48% increase over the previous year. This corresponds to 48% of total world production. Europe came second in 2003 with 202 MWp, a 43% increase over the previous year, and corresponding to 27% of world production. Production in the United States reached only 109 MW, however, a decrease of 6%, with the global share of US production falling dramatically from 21% in 2002 to 14% in 2003.

The rest of the world, with its key players in Australia and India, produced 85 MWp in 2003. Of particular interest is how production capacity in China will develop over the next few years. The Chinese company Suntech announced an expected cell production capacity of 75 MWp by the end of 2004 and further expansion to 150 MWp in 2005. Overall, the growth of global PV shipments since 1995 can be seen in Table 2.2.

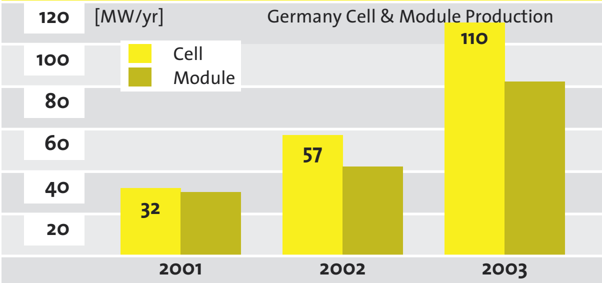
The leading manufacturers of solar cells can be seen in Table 2.1. Although until a few years ago the market was dominated by BP Solar, a subsidiary of the multinational oil company, this situation has radically changed with the entry of new Japanese and European players. In 2003, the two leading producers of PV cells/modules were Sharp and Kyocera, both Japanese companies. Sharp further strengthened its position as leading cell producer with an increase in production to 197 MWp, which corresponds to roughly 25% of world production. A breakdown of the main companies' involvement in regional and country markets can be seen in Table 2.1. The latest world market survey by trade magazine Photon International (April 2004) records 298 types of modules being produced by 78 different manufacturers in more than a dozen different countries.

Europe has seen an expansion in production from traditional cell producers such as RWE Schott Solar, which increased its cell production from 29.5 MWp in 2002 to 44 MWp in 2003, and Isofoton, which increased from 27 MWp in 2002 to 35.2 MWp in 2003. New players in the market are also showing impressive growth rates. The German company Q-Cells, for example, expanded its production from 9 MWp (2002) to 28.2 MWp (2003), while Deutsche Cell expanded from 1 MWp (2002) to 17 MWp (2003).

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.

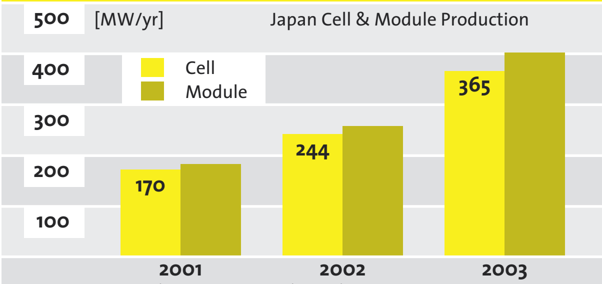
This is why the relative stability of systems like the German Renewable Energy Law (see Part Three: The Solar Race) has proved crucial to business commitment. In anticipation of a flourishing market, Germany has seen a steady increase in both solar cell and module manufacture from 1995 onwards. During 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 cells increased from 32 MWp (2001) to 110 MWp (2003) and of modules from 31 MWp (2001) to 80 MWp (2003). It is anticipated that cell production will increase to 500 MWp, and module production to 380 MWp, by the end of 2006. For comparison, in the same period (2001-3) Japanese production of solar cells rose from 170 to 365 MWp and of modules from 172 to 400 MWp.

Figure 2.1: Development of solar manufacture in Germany



Source: International Energy Agency – Photovoltaic Power Systems Programme

Figure 2.2: Development of solar manufacture in Japan



Source: International Energy Agency – Photovoltaic Power Systems Programme

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.

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 € 0.25/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,

Table 2.1: PV cell manufacture – leading producers by region				
Region	**Total shipments in 2003**	**Growth from 2002**	**Leading producers**	**Shipments in 2003**
Europe	202.3 MW_{peak}	43.5%	RWE-Schott Solar (Germany)	40.0 MW_{peak}
			Isofoton (Spain)	35.2 MW_{peak}
			Q-Cells (Germany)	28.2 MW_{peak}
			Deutsche Cell (Germany)	17.0 MW_{peak}
			Photowatt-France (France)	17.0 MW_{peak}
			BP Solar (Spain)	15.5 MW_{peak}
			Ersol (Germany)	9.0 MW_{peak}
			Shell (Germany/ Netherlands)	9.0 MW_{peak}
			Sunways (Germany)	6.7 MW_{peak}
			Astro Power (Spain)	5.5 MW_{peak}
			Antec (Germany)	5.0 MW_{peak}
United States	109.0 MW_{peak}	- 5.7%	Shell Solar	53.0 MW_{peak}
			Astro Power	24.2 MW_{peak}
			BP Solar	13.4 MW_{peak}
			USSC	7.0 MW_{peak}
			RWE Schott Solar	4.0 MW_{peak}
Japan	365.4 MW_{peak}	47.8%	Sharp	197.9 MW_{peak}
			Kyocera	72.0 MW_{peak}
			Mitsubishi Electric	42.0 MW_{peak}
			Sanyo	35.0 MW_{peak}
			Kaneka	13.5 MW_{peak}
			Mitsubishi Heavy Industries	3.0 MW_{peak}
Rest of the World	85.3 MW_{peak}	54.9%	BP Solar (Australia)	26.0 MW_{peak}
			Motech (Taiwan)	17.0 MW_{peak}
			BP Solar (India)	14.0 MW_{peak}
			Suntech (China)	9.0 MW_{peak}

Note: This table includes most manufacturers with production over 3 MWp in 2003. Source: Photon 04/2004

Table 2.2: Growth in world PV production 1995-2003 [MW_{peak}]									
Region	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003***
Japan	16.40	21.20	35.00	49.00	80.00	128.60	171.22	251.07	365.4
Europe	20.10	18.80	30.40	33.50	40.00	60.66	86.38	135.05	202.3
US	34.75	38.85	51.00	53.70	60.80	74.97	100.32	120.60	109.0
ROW	6.35	9.75	9.40	18.70	20.50	23.42	32.62	55.05	85,3
Total	77.60	88.60	125.80	154.90	201.30	287.65	390.54	561.70	762. 0

*Source: PV News, *Photon*

however, where subsidies were cut dramatically by 50% in March 2004, 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 which 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 60% of installation costs are represented by the module, 15% by the inverter and 25% by balance of system components and assembly of the unit.

EPIA's aims for further improvements include:

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 80 MW, while the 2003 production capacity in Germany alone was 110 MWp, clearly indicates the potential for automisation 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 which are already wafer thin and the correct width for use as PV cells. This method is being pioneered by RWE Schott Solar at one of its factories. EPIA has adopted the following technological aims in this field for 2010 (2020):

- *Material (Si) consumption for mono crystallline-Silicon from 16 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 µm to 180 µm (continuing to 100 µm)*
- *Kerf loss in the sawing process from 250 µm to 160 µm (continuing to 150 µm)*

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 monocrystalline silicon from 16.5% to 20% (continuing to 22%)*
- *Efficiency increase for multicrystalline 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/µc-Si, CIS and CdTe) (continuing to 15%)*
- *Building integrated PV (BIPV) with low cost per m², price reduction of 50% (continuing with 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 both 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 publics that there are important social and environmental benefits to be captured.

The argument in countries like Japan and Germany 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 which will soon see others joining the pursuit.

Germany

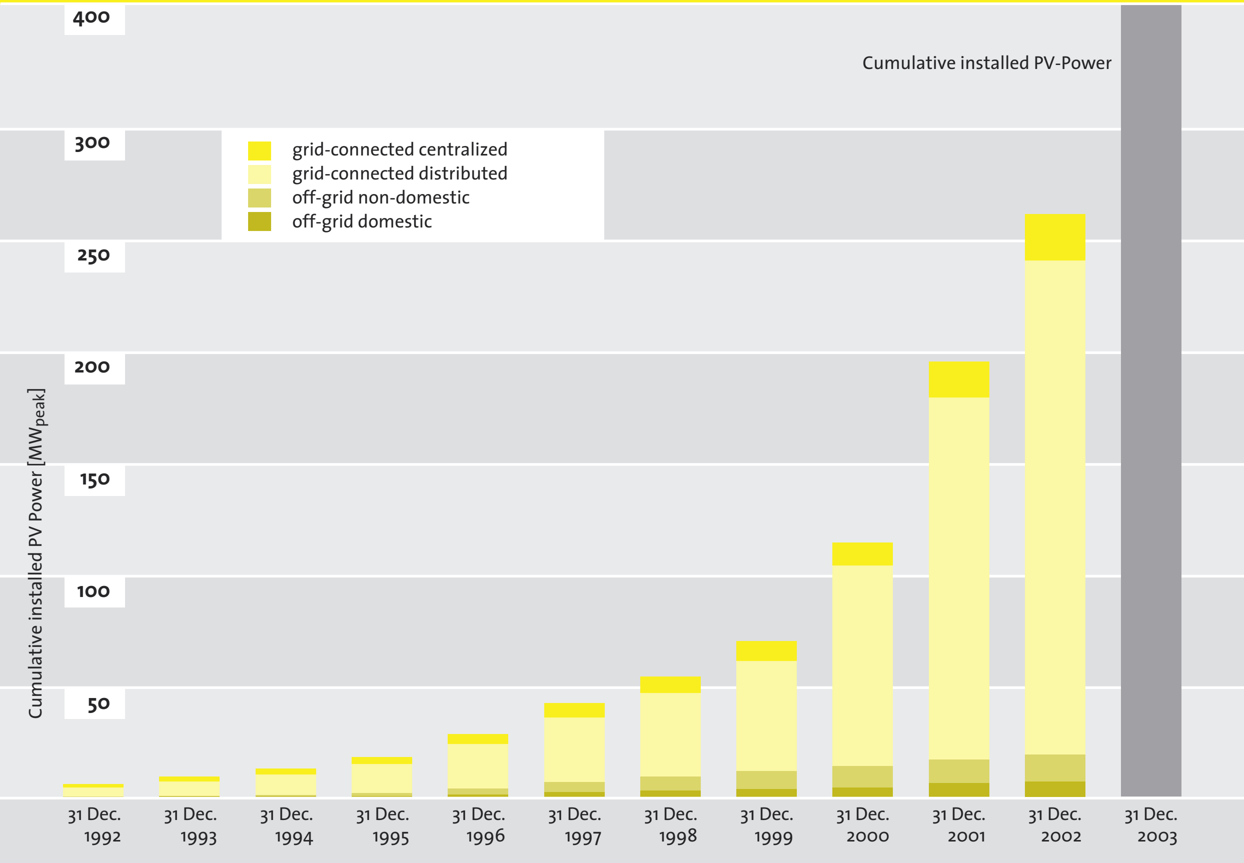
- *PV capacity end 2003: 416 MWp*
- *Support system: Premium price per kWh, financing opportunities from the German Bank for Reconstruction*

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 2003 total capacity had reached 416 MWp, with 130 MWp installed last year alone. In the 2001 edition of Solar Generation it was ambitiously estimated that the country could achieve a figure of 438 MWp by 2004. This has in fact been almost reached by the end of 2003, and with the expectation that more than 650 MWp will be installed by the end of 2004.

In 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 15,000 MW installed, representing roughly 5% of electricity supply, and an

Figure 3.1: Installed PV in Germany by sub-market *Source: IEA- PVPS*



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 connected 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 superseded 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 300 MWp. For both private households and businesses the incentive came through a guaranteed ten year low interest loan (1.9% per annum), and 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 generation 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 41.66 MW. 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 below). There are also still possibilities to receive a low interest rate loan for investment in a PV system, for example under the CO_2 abatement programme.

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

- *345.5 MWp installed*
- *Total investment by customers € 1.77 billion*
- *Market volume increase from 12 MWp in 1999 to 130 MWp 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 bulk production of carbon-free power. Public funding of R&D, about € 17,25m 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.

Table 3.1: PV feed-in tariffs under REL from 2004 in Euro-cents per kWh

Year	2004	2005	2006	2007	2008
Roof	57.40	54.53	51.80	49.21	46.75
Above 30 kW	54.60	51.87	49.28	46.82	44.48
Above 100 kW	54.00	51.30	48.74	46.30	43.99
Facade bonus	5.00	5.00	5.00	5.00	5.00
Open space	45.70	43.42	40.60	37.96	35.49

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 which should be excellent tools for getting the PV market moving. These include:*
  - *41.4 € cents/kWh up to system sizes of 100 kWp (until 150 MWp installed, then new calculation of the tariff for further systems)*
  - *21.6 € cents/kWh for system sizes above 100 kWp (until 200 MWp installed, then new calculation of the tariff for further systems)*
  - *payment period fixed at 25 years, then reduced to 80%.*
- ***Italy*** *launched a solar roof programme in 2001, but success has been very limited. The Italian parliament has decided to introduce a premium feed-in tariff, but the level of the tariff and other conditions have not yet been defined.*
- ***Luxemburg*** *has an extremely attractive support system, with investment support and up to 45 € cents/kWh feed-in tariff.*
- *The* ***United Kingdom*** *had 5.9 MWp 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*** *introduced a national feed-in tariff at the beginning of 2003. Due to the very limited installed capacity (15 MWp) supported, applications were accepted for a period of less than one month.*
- *In* ***Greece*** *the implementation of a feed in tariff for PV is under discussion.*
- *Other European countries are also pursuing solar programmes, mainly targeted at the grid-connected sector.*

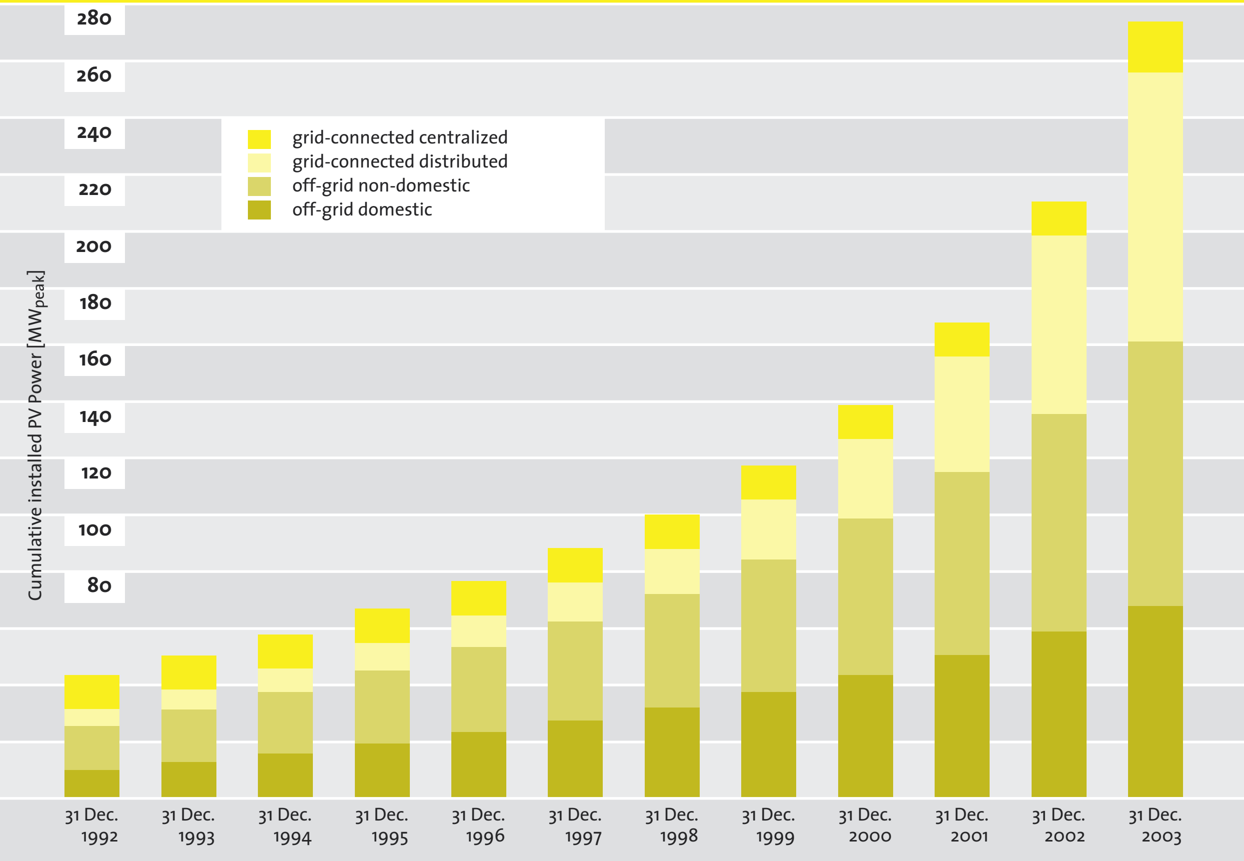
USA

- *PV capacity end 2003: 275 MWp*
- *Support system: Federal tax credit plus separate state incentives; Million Solar Roofs Initiative.*

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

Figure 3.2: Installed PV in the United States by sub-market

Source: IEA- PVPS



industry's goal is to sustain a 30 to 35% annual growth over the next 20 years. In terms of installations, PV has reached a level of 275 MWp, with 63 MWp being installed during 2003.

Access to PV systems is growing fast in California, but is limited in the rest of the country. Over 80% of systems have been installed in California, where more than 4 out of 5 people favour doubling the state's supply of renewable energy sources by 2010. Other states, including Arizona, Connecticut, Maine, Massachusetts, Nevada, New Jersey, New Mexico, Pennsylvania, Texas and Wisconsin have introduced Renewable Portfolio Standard programs, which have increased renewable energy use, but have had a limited impact on PV development.

The US PV production market is largely in the hands of multinational companies. AstroPower has been bought by General Electric, while the biggest US producers, Shell Solar and BP Solar, account for nearly two thirds of solar cell production.

ECONOMICS

There is no national price incentive programme for PV, as in Germany, and support is largely dependent on individual state initiatives. "Commercial" PV (not domestic) is eligible for a federal 10% tax credit, but this has not been enough by itself to stimulate the market.

Various support measures have been considered by the US Congress. The 2001 National Energy Security Policy Act, for instance, would have offered a 15% residential solar tax credit of up to $ 2,000 and a **buy-down** payment starting at $ 3 per watt of installed capacity. The buy-down (capital subsidy) programme already operating in California, which offers $ 3 per watt, resulted last year in 400 grid-connected systems of 2-4 kW capacity being installed.

The US PV industry has also benefited from state incentives and policies designed to increase the use of renewable energy. A number of initiatives beneficial to solar power, including **green pricing** schemes (where consumers agree to pay extra for a supply of renewable electricity), **renewables portfolio standards** (commitment that a specific percentage of the state's power should come from renewables), and **system benefit charges** (where a levy is made on all electricity users to fund renewables) have been passed by individual states. In addition, more than 35 states have introduced **net metering**, where the power utility agrees to pay the same amount for the output from a solar system as consumers pay for their supply.

RESEARCH AND DEVELOPMENT PROGRAMS

The US Department of Energy directs research focused on increasing domestic capacity by lowering the cost of delivered electricity and improving the efficiency of PV modules and systems.

Specific goals up to 2006 are to:

- *Reduce the direct manufacturing cost of PV modules by 30% to $ 1.75/W*
- *Establish greater than 20 year lifetimes for PV systems by improving the reliability of balance-of-system components and reducing recurring costs by 40%*
- *Work with the PV industry to facilitate achievement of its roadmap goals of 1 GW cumulative US sales (export and domestic) by 2006*
- *Ensure that the National Solar Program shares the costs in areas of fundamental research, technology development and advanced materials and devices*

The total federal budget for the photovoltaic component of the National PV Subprogram totalled $ 64 million in 2003, with additional Congressional funding of $ 10.7 million for the Million Solar Roofs Program, an inverter initiative and various specific PV installations.

FUTURE PROSPECTS

Government projections suggest that solar PV will be the fastest growing source of generation in the US over the next 20 years, with its use expanding at a rate of more than 19% per year up to 2020. All renewables, including geothermal, biomass and wind, could be providing 8% of the country's electricity over the same time scale.

The US PV industry has meanwhile presented a longer term strategy which looks further ahead than the five year cycles of the government's PV programme. Marking out a 20 year roadmap for research, technology and market priorities, this framework assumes a world wide annual growth rate of 25% up to 2020, and with the goal of reaching a 40% share for US module manufacturers. By 2020, this means that the US industry could be supplying at least 6 GW to be installed world wide, with 15 GW installed in the US itself. On that basis the PV industry would be approaching a turnover of $ 10 billion a year, creating tens of thousands of jobs and enormous environmental benefits.

The future for PV in the US is crucially dependent, however, on the ongoing stance on energy issues taken by the Bush administration, especially over climate change. At the time of writing the US has still refused to sign up to the latest international agreement resulting from the Kyoto Protocol, which details how developed countries will reduce their greenhouse gas emissions.

On current trends US Americans are expected to use 27% more energy in 2020 compared to 1998, with electricity use increasing the fastest. Without a significant commitment to energy efficiency and renewable energy, high electricity consumption could result in 1,000 new power plants being built by 2020, the vast majority powered by fossil fuels.

Meanwhile, the United States has tumbled from its position as a leader in the solar industry. In 1995 the US produced 45% of the world's solar cells, but the lack of a national policy promoting solar energy has held growth down. Without the support of state governments such as California (see box), the country would have fallen even further behind.

State Initiatives in the US

Solar Initiatives in California

California is driving the US market for solar energy almost entirely because of incentive programs offered through the state's electricity suppliers. The main subsidy programs are the California Energy Commission's Emerging Renewables Program - which offers $ 3 per watt towards capital costs and resulted in 3,200 solar installations in 2003 - the California Public Utility Commission's Self-Generation Incentive Program and programs run by Los Angeles Department of Water and Power and Sacramento Municipal Utility District. PV installations under these and a handful of other small programs reached 14 MW in 2002 and 26 MW in 2003, with a total of nearly 79 MW installed by June 2004. The California Energy Commission has also simplified the rules and tariffs for net metering, and reduced the paperwork for interconnection requirements for grid-connected photovoltaic systems.

San Diego: *The city of San Diego has committed to a first-of-its-kind clean energy initiative to meet the city's growing electricity demand. Under this plan, San Diego will generate 50 MW of clean energy over the next ten years to meet the region's projected energy shortfalls and stop another energy crisis. The City is expected to meet the majority of that demand with solar power. This is the first time a major US city council has initiated such a plan as the solution to its energy needs, and was a major victory for the Greenpeace Clean Energy Now team.*

San Francisco: *In November 2001, San Francisco voters approved a $ 100 million revenue bond for renewable energy and energy efficiency that pays for itself from the savings, costing taxpayers nothing. The bond pays for solar panels, wind turbines and energy efficiency measures for public buildings. The money that would have gone to buy electricity from power plants instead goes to finance the bond.*

University of California: *The university is committed to install 10 MW of solar units across its ten campus network. Greenpeace was instrumental in securing this commitment.*

Other State Initiatives

- *The state of* ***New Jersey*** *offers a $ 5.50/Wp subsidy for photovoltaic systems. The Clean Energy Rebate Program has budgeted $ 16.2 million up to 2008. The program has supported (or reserved incentives for) 91 projects totalling over 3,300 kW of power.*
- ***Illinois:*** *LLed by the strong "Brightfields" program in Chicago, where abandoned "brownfield" factory sites are converted to either photovoltaic manufacturing plants (owned and operated by Spire Corporation) or installed photovoltaic systems. The state of Illinois passed the largest subsidy in the United States for photovoltaic systems, $ 6/Wp. Over 1 MW of PV was installed in the state in 2002.*
- ***New York:*** *New York has agreed over $ 50 million to support new industry, new installations and studies to accelerate commercialisation of photovoltaic systems. New York increased the photovoltaic subsidy to $ 5/W in May 2002 for grid-connected systems.*
- ***Virginia:*** *Virginia offers a $ 0.75/W cash rebate for installed photovoltaic modules produced in the state. This program is capped at $ 6 million per year.*
- ***Connecticut:*** *The Connecticut Clean Energy fund has allocated $ 5.3 million in subsidies, with $ 5.75/Wp offered for residential PV systems.*
- ***Nevada:*** *The Nevada Demonstration Program offers up to $ 5/W for residential, small businesses, Indian tribes and schools. The program has $ 20 million to distribute over 3 years.*
- ***North Carolina:*** *Carolina offers a 35% tax credit for photovoltaic system installations.*
- ***Ohio:*** *Support for 50 public schools to have photovoltaic systems/training modules installed.*

Japan

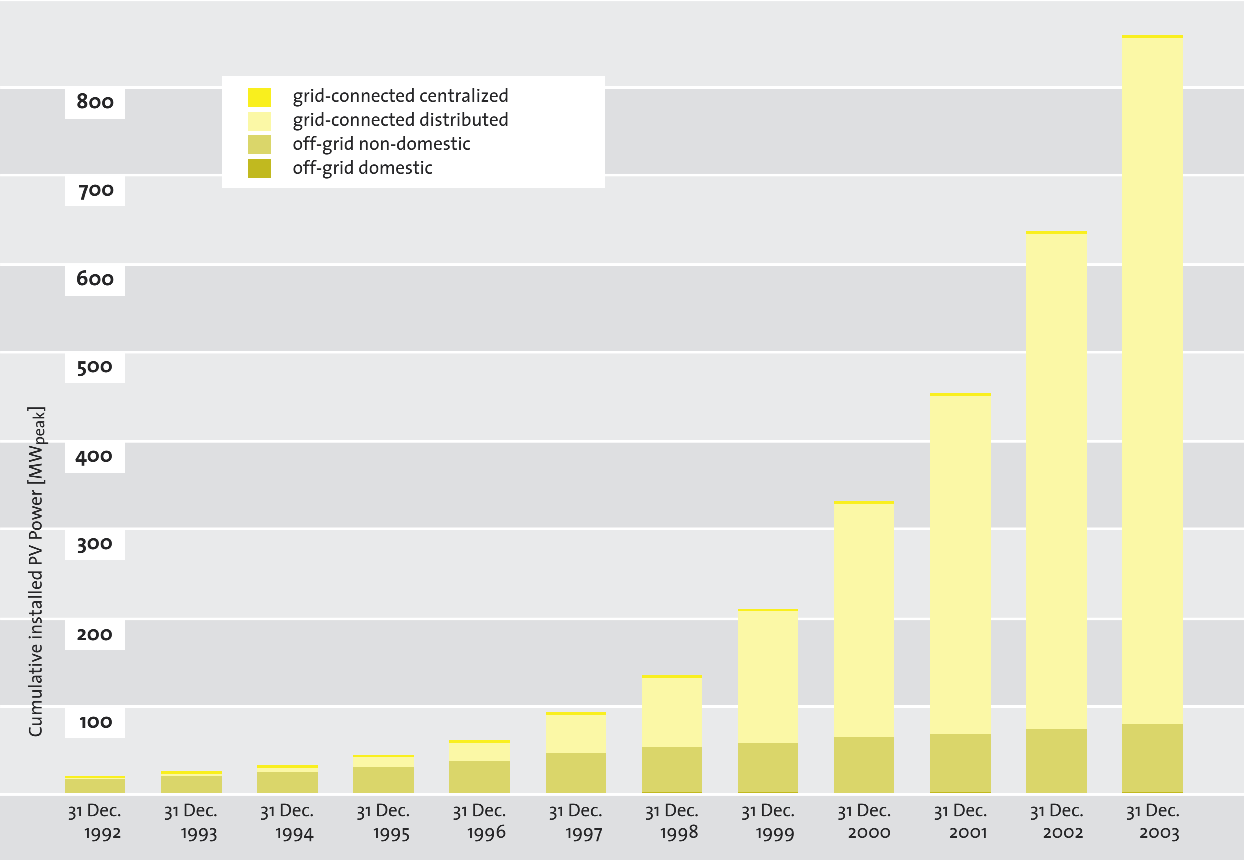
- *PV capacity end 2003: 860 MWp*
- *Support system: Various government programmes, including grants for domestic PV roofs, and net metering support provided by utilities*

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 2003 a total of 860 MWp had been installed in Japan, with government plans for 4.8 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.

The national Japanese programme is aimed at rapid expansion in the number of units coupled with a decreasing percentage of subsidy. The overall goal is to stimulate production, bring prices down, create market awareness and leave Japanese industry with a fully economic market which 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 cut from $ 223 million in 2002 to $ 100 million in 2003, and by a further 50% this year. This reduced the subsidy per kWp from $ 862/kWp in 2003 to $ 430/kWp in 2004. Even so, the market has continued to grow, the number of subsidy applications increased during 2003, while the price for PV

Figure 3.3: Installed PV in Japan by sub-market *Source: IEA- PVPS*



installed capacity has continued to fall to a present level of about $ 6,500/kWp. One specific result is that the National Institute of Advanced Industrial Science and Technology in Tsukuba, Ibaraki has installed PV demonstration facilities amounting to over 1 MWp. This is the largest ever in Japan, providing 1 GWh of clean electricity and a CO_2 reduction of 300 tons annually.

GOVERNMENT SUPPORT

The Japanese government has focussed large financial resources on the PV market in order to establish internationally competitive mass production. Comprehensive financial, tax and system support measures are used to promote solar and other "new energy" (renewable) technologies which 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.

The following programmes are in place for PV promotion and technological development.

Table 3.2: Japanese PV support programmes	Budget for FY2004 in $ million
Residential PV system dissemination programme	50.5
Field test projects on PV power generation systems for industrial and other applications	1.3
Field test projects on advanced PV power generation technologies	48.4
Research and development of PV generation technologies	62.9
International cooperative Demonstration Acceleration	20.3
Demonstration development of centralised grid-connected PV system	57.1
Total	**240.5**

While most of the budgets had been cut compared to the previous year, the two programmes covering advanced PV power generation technologies and centralised grid-connected PV systems have seen an increase of almost 90% compared to 2003.

PART THREE: THE SOLAR RACE

Japan's national programmes for renewables during 2004 include:

- ***RPS Law (2003)*** *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 Industrialists*** *supports businesses which 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 was monetised for customers, however, PV would be able to compete much earlier than expected.

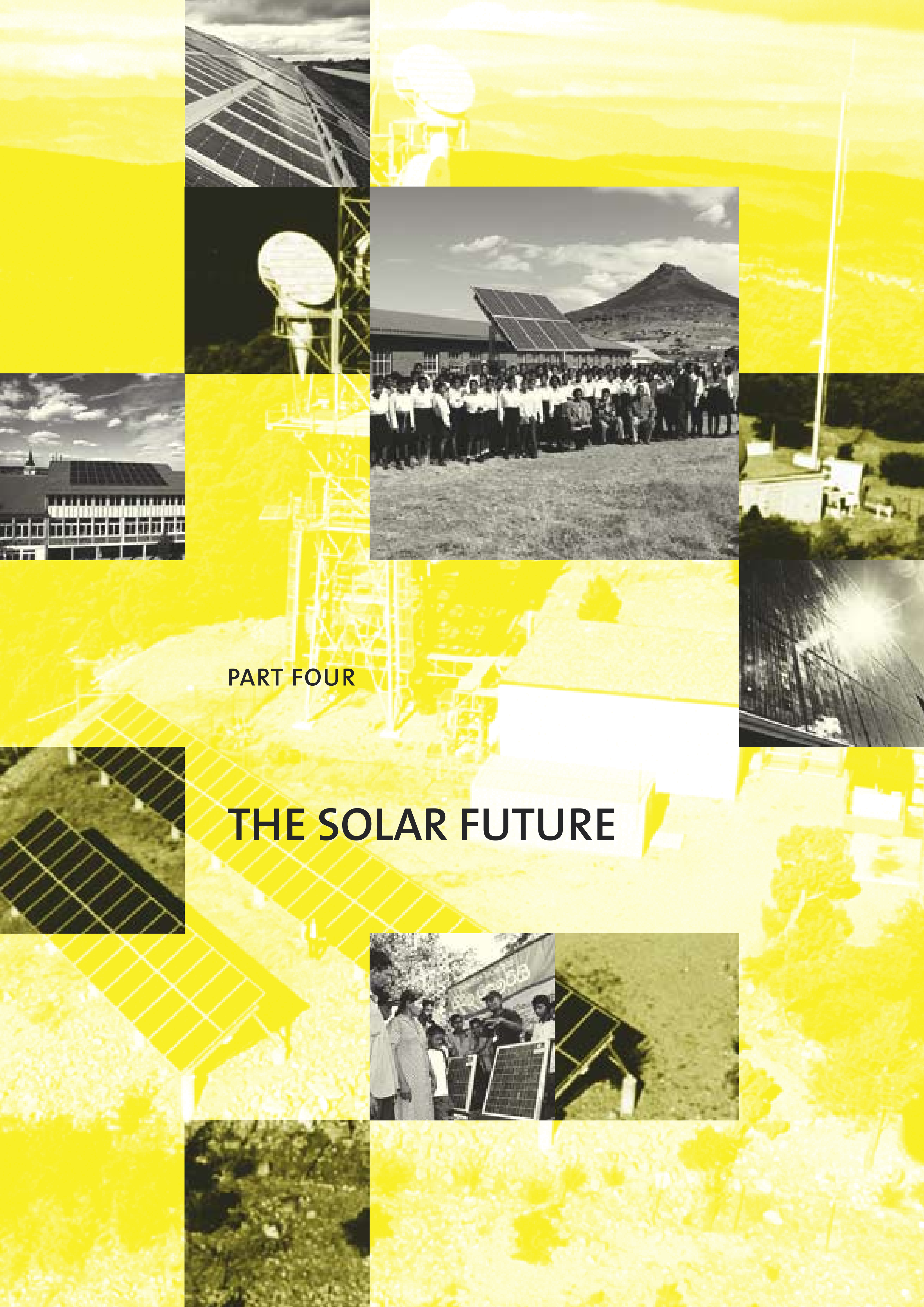
One other factor is the introduction of premium green pricing for renewable electricity. All ten Japanese regional power utilities introduced a "Green Power Fund" at a monthly rate of $ 1-4 from October 2000, with the companies matching this amount towards the installation of new renewable plants. Most 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, Japan announced (in 2001) an accelerated target to install 4,820 MW of PV by 2010. Projections by the Japan Photovoltaic Energy Association (JPEA) show that annual installations could reach 1,230 MWp 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 4,300 MWp by 2020, with a total capacity of 28,700 MWp installed. For 2030 the goal is to reach an annual market of 10,000 MWp, with a cumulative installed capacity of 82,800 MWp. By then the PV industry in Japan would have created 300,000 jobs, the PV installation rate would 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 & Assumptions

If PV is to have a promising future as a major energy source it must build on the experiences of those countries which have already led the way in stimulating the solar energy market. In this section of the report 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 which would be created and the crucial effect which an increased input from solar electricity will have on greenhouse gas emissions.

This scenario for the year 2020, 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 US, 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 27%, then rising to 34% between 2010 and 2020. Initial growth is expected to be fastest in the grid-connected sector, but by 2010 growth rates in the emerging off-grid rural sector are expected to have overtaken, 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 2020, 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 15,300 TWh in 2000 to 20,900 TWh in 2010 and 25,579 TWh by 2020.

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 2020-2040 a very conservative lifetime of 25 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 25 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

These are the headline findings of the Greenpeace/EPIA "Solar Generation" scenario. They 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.

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

Global Solar Electricity Output in 2020:	**282 TWh**
	= 10% of EU-25 electricity demand in 2003
	= 1.1% of global electricity demand
Global Solar Electricity Output in 2040:	**7,442 TWh**
	= 21% of global electricity demand
Detailed Projections for 2020:	
PV systems capacity	205 GWp
Grid-connected consumers	93 million world wide[1]
	31 million in Europe
Off-grid consumers	950 million world wide[2]
Employment potential	2.25 million full-time jobs world wide
Investment value	€ 62 billion per annum
Prices for grid connected PV systems	Reduction to € 2 per Wp
Cumulative carbon savings	730 million tonnes of CO_2

1. Calculation basis: 2.5 persons per household, with an annual consumption of 3,800 kWh
2. Calculation basis: A 100 W solar system will cover the basic energy needs of 3-4 people

1. Power Generation

The Greenpeace/EPIA scenario shows that by the year 2020, PV systems could be generating approximately 282 Terawatt hours of electricity around the world. This means that enough solar power would be produced globally in twenty years' time to

Table 4.2: Projected growth of world solar power market up to 2020					
Year	Annual Installed Capacity [MW]	Annual Growth Rate [%]	Estimated Annual PV Electricity Production [MWh]	Estimated Reduction of CO_2 [tCO_2]	Estimated Jobs
1995	*Market datas from EPIA, all other figures calculated* 79	12.3	539,148	323,488	4,343
1996	89	13.5	661,246	396,747	4,932
1997	126	41.6	834,103	500,461	6,908
1998	153	21.1	1,044,000	626,400	8,410
1999	201	31.9	1,319,748	791,848	10,950
2000	259	38.0	1,675,065	1,005,039	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	approx. 37.0	4,471,497	2,682,898	34,702
2005	985	28.0	5,739,803	3,443,882	43,011
2006	1,283	28.0	7,405,441	4,443,265	55,696
2007	1,675	28.0	9,599,060	5,759,436	70,479
2008	2,192	28.0	12,496,836	7,498,101	91,237
2009	2,877	28.0	16,337,415	9,802,449	118,099
2010	3,634	35.0	21,206,382	12,723,829	149,585
2011	4,609	35.0	27,403,933	16,442,360	194,296
2012	5,870	35.0	35,326,026	21,195,615	252,871
2013	7,511	35.0	45,497,490	27,298,494	329,815
2014	9,656	35.0	58,617,385	35,170,431	431,174
2015	12,475	35.0	75,621,343	45,372,806	565,100
2016	16,199	35.0	97,767,586	58,660,552	742,625
2017	21,146	35.0	126,755,998	76,053,599	978,731
2018	27,753	35.0	164,893,480	98,936,088	1,293,846
2019	36,622	35.0	215,324,289	129,194,573	1,715,930
2020	48,590	35.0	282,351,761	169,411,057	2,262,749
2000 to 2020	205,518		1,215,755,982	730,266,385	9,410,810

satisfy the current electricity needs of 10% of the expanded European Community (EU 25).

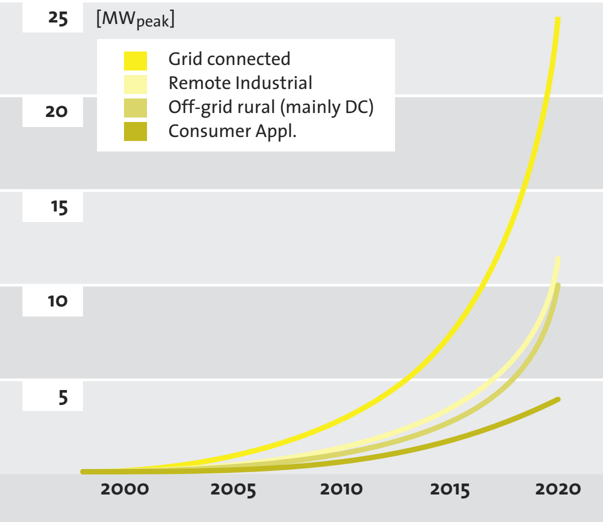
The global installed capacity of solar power systems would reach 205 GWp by 2020. More than half of this would be in the grid-connected market, mainly in industrialised countries. Assuming that 80% of these systems are installed on residential buildings, and their average size is 3 kWp, each serving the needs of three people, the total number of people by then generating their own electricity from a grid-connected solar system would reach 93 million. In Europe alone there would be roughly 31 million people receiving their supply from grid-connected solar electricity[1].

In the non-industrialised world approximately 30 GWp of solar capacity is expected to have been installed by 2020 in the rural electrification sector. Here the assumption is that as an 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.** This would represent a major breakthrough for the technology from its present emerging status.

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

PART FOUR: THE SOLAR FUTURE

Figure 4.1: Growth in world solar market by application



By 2040, the penetration of solar generation would be even deeper. Assuming that overall global power consumption had by then increased from 25,578 to 36,000 TWh, **the solar contribution would equal 21% of the world's electricity output.** 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 today's 17 jobs per MW in production will be reduced to 15 in 2010, 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 26 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 of 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 2 jobs per MW by 2020.

The result is that by 2020, **an estimated 2.25 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

Table 4.3: Employment in PV related jobs world wide

Year	Jobs in Production	Jobs in installation, retailing	Jobs in main-tenance	Total
2003	8,144	17,451	2,354	27,949
2004	9,027	22,568	3,106	34,701
2005	9,733	29,199	4,079	43,011
2006	12,589	37,768	5,338	55,695
2007	14,657	48,856	6,967	70,480
2008	18,961	63,203	9,073	91,237
2009	24,531	81,769	11,799	118,099
2010	27,950	104,813	16,822	149,585
2011	35,907	134,651	23,738	194,296
2012	46,240	173,401	33,230	252,871
2013	59,701	223,880	46,234	329,815
2014	77,294	289,852	64,029	431,175
2015	100,364	376,366	88,370	565,100
2016	130,727	490,226	121,673	742,625
2017	170,834	640,629	167,268	978,731
2018	224,017	840,065	229,764	1,293,846
2019	294,815	1,105,555	315,561	1,715,931
2020	389,438	1,460,391	412,920	2,262,749

3. Costs and Investment

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 from today's € 1.69 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.**

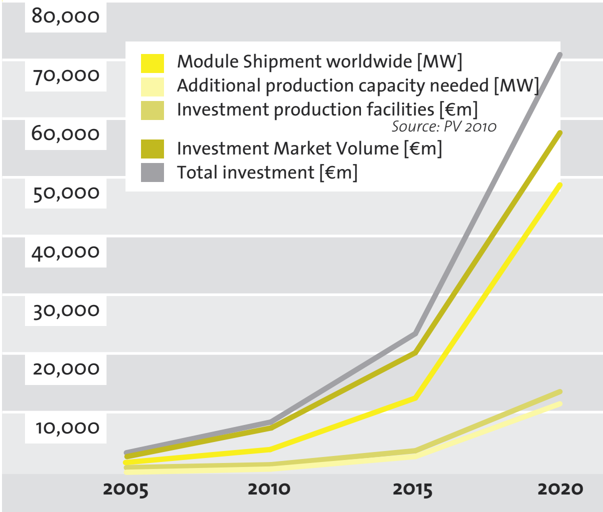
In terms of delivered electricity, it is possible to make predictions for the output from grid-connected systems. The results are given for an average consumer in some of the major cities of the world (see Table 4.4). These show that by 2020 the cost of solar electricity in the most insolated regions - 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.

Of equal importance in relation to falling costs is the level of investment in manufacturing capacity. Here the scenario

Table 4.4: Fall in Price of PV electricity in selected cities 2000-2020

Region	kWh/ (year* kWp)	2005 €/ kWh	2010 €/ kWh	2015 €/ kWh	2020 €/ kWh
Berlin	900	0.40	0.30	0.26	0.19
Paris	1000	0.36	0.27	0.24	0.18
Washington	1200	0.30	0.23	0.20	0.15
Hongkong	1300	0.28	0.21	0.18	0.13
Sydney	1400	0.26	0.19	0.17	0.13
Mumbai	1400	0.26	0.19	0.17	0.13
Bangkok	1600	0.23	0.17	0.15	0.11
Dubai	1800	0.20	0.15	0.13	0.10

Figure 4.3: Global Investment in new PV prduction facilities



shows that **the global value of the solar power market will have reached more than € 70 billion by the end of the scenario period.** Investment in new production facilities will reach € 13.2 billion by 2020. The overall market volume for PV systems will increase to € 62 billion. Just over € 9.6 billion of that value will be located in Europe, € 8.7 billion in the Pacific region and € 5.6 billion in Africa.

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.

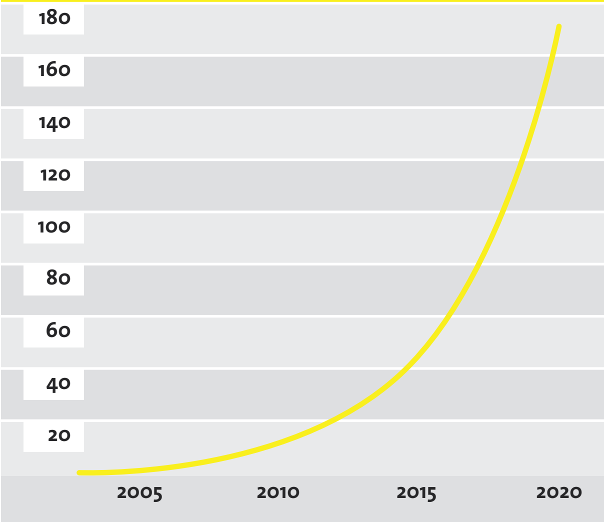
Table 4.5: Value of regional PV market in Million €

Year	OECD Europe	OECD N. America	OECD Pacific	Latin America	East Asia	South Asia	China	Middle East	Africa	ROW	Total
2003	625	220	798	129	39	52	98	23	77	14	2,075
2004	1,001	247	890	157	49	57	128	27	90	15	2,661
2005	1,073	278	1,043	191	62	69	150	31	105	17	3,019
2006	1,258	378	1,272	234	78	87	183	47	133	21	3,691
2007	1,477	515	1,553	285	99	110	224	71	168	25	4,527
2008	1,734	702	1,896	348	126	140	274	107	214	31	5,572
2009	2,037	956	2,317	425	159	178	334	160	271	38	6,875
2010	2,348	1,169	2,616	540	217	242	456	204	357	50	8,199
2011	2,708	1,431	2,955	687	297	331	622	259	471	66	9,827
2012	3,123	1,752	3,339	873	405	452	850	329	620	87	11,830
2013	3,602	2,144	3,773	1,110	553	617	1,160	419	818	115	14,311
2014	4,154	2,624	4,262	1,410	755	842	1,584	532	1,078	151	17,392
2015	4,790	3,211	4,814	1,792	1,030	1,149	2,161	676	1,420	199	21,242
2016	5,521	3,927	5,435	2,276	1,406	1,567	2,948	858	1,871	262	26,071
2017	6,359	4,801	6,133	2,889	1,917	2,137	4,020	1,090	2,463	345	32,154
2018	7,321	5,865	6,916	3,665	2,612	2,912	5,478	1,383	3,240	454	39,846
2019	8,421	7,160	7,793	4,647	3,556	3,965	7,458	1,753	4,260	597	49,610
2020	9,679	8,734	8,775	5,886	4,838	5,395	10,147	2,220	5,596	785	62,054

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 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.

Figure 4.5: Annual global CO_2 savings [million tonnes]



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 2020 the Solar Generation scenario shows that the worldwide expansion of PV would be reducing annual CO_2 emissions by 169 million tonnes. This reduction is equivalent to the emissions from all 45 million cars currently operating in Germany, or the entire CO_2 emissions from the Netherlands. Cumulative carbon dioxide savings from solar electricity generation between 2000 and 2020 will reach a level of 664 million tonnes, equivalent to two-thirds of Germany's CO_2 emissions in 2000 (or almost as much as the total emissions from Canada or Brazil).

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 uncertainty, 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 € cents/kWh. These external costs must be taken into account when comparing solar systems with other energy sources.

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 US, 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 2020 installed PV capacity in the OECD regions will have fallen to less than half the world total (see Figures 4.6-4.8).

Figure 4.6: World solar power market by region 2003

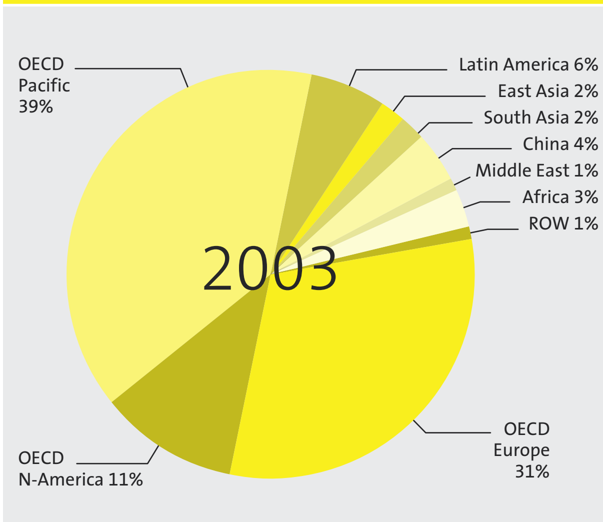


Figure 4.7: World solar power market by region 2010

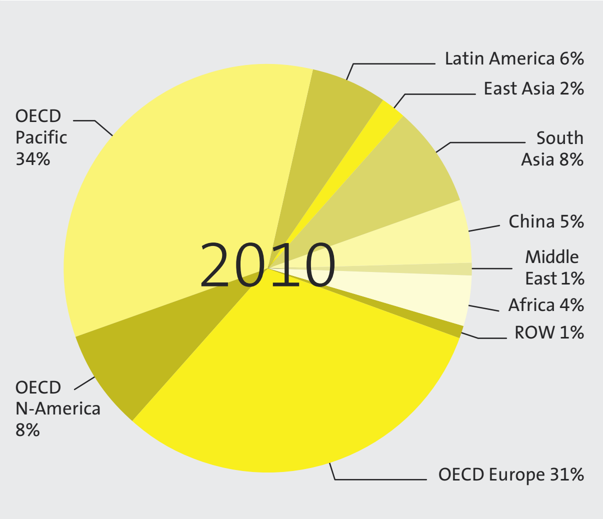
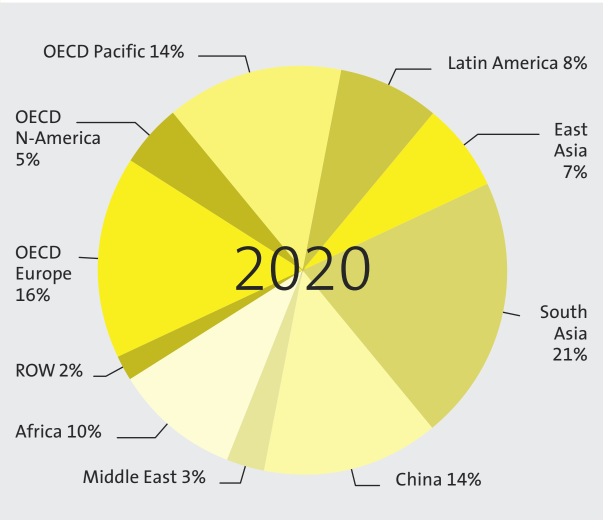


Figure 4.8: World solar power market by region 2020



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 the year 2010. This scenario demonstrates that this goal can be exceeded and a capacity of almost 5 GWp in Europe by 2010 is possible.

Reasons for this optimism include the fact that the PV market in Germany grew by 56% between 2002 and 2003. This demonstrates the impressive growth rates which 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 edition 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 is about to do so, also adopting a premium feed-in tariff for solar electricity. Luxembourg has a combination of feed-in tariff and investment support, resulting in the highest per capita installed PV capacity in the world. Greece is also planning to introduce a solar electricity programme in the near future.

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 tariffs 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 which 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 is expected to be 30%. Following the conclusion of the roofs programme in 2003, however, the annual growth rate is assumed to drop to 25% between 2006 and 2009 and to 20% between 2010 and 2020.

Table 4.6 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 3.2 TWh by 2010. This is equivalent to the output of a centralised coal-fired power plant. By 2015 solar electricity would cover more than 1.5% of Germany's electricity demand and by 2020 more than 3.5%. The cumulative installed capacity would reach 18,477 MW by 2020.

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 50,000 additional jobs.

Government policy and programmes

Following a 1,000 roofs programme in the 1990s, the 100,000 roofs programme was introduced in 1999, a programme that provided low interest loans for the purchase of PV systems. By itself, this 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 300 MWp.

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.*
- *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 pay back 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

Table 4.6: Solar market in Germany to 2020

Year	MW	MWh	tCO_2	Market Volume in €m	Jobs
2003	139	347,500	208,500	473	4,265
2005	320	806,900	484,140	953	9,900
2010	644	3,288,096	1,972,858	1,404	19,869
2020	2,604	18,316,491	10,989,895	3,076	80,380
Total 2000 to 2020	18,477	15,016,932	66,964,140		

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 the year 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 both 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 4.7: Cumulative installed PV power in Australia by sub-market

Sub-market / application	31 Dec. 1992 kWp	31 Dec. 1993 kWp	31 Dec. 1994 kWp	31 Dec. 1995 kWp	31 Dec. 1996 kWp	31 Dec. 1997 kWp	31 Dec. 1998 kWp	31 Dec. 1999 kWp	31 Dec. 2000 kWp	31 Dec. 2001 kWp	31 Dec. 2002 kWp	31 Dec. 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
off-grid non domestic	5,760	6,865	8,080	9,380	11,520	13,320	15,080	16,360	17,060	19,170	22,740	26,060
grid connected distributed		5	20	30	80	200	850	1,490	2,390	2,800	3,400	4,630
grid connected centralized				20	20	320	630	650	650	650	850	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**

Notes: 1. Grid connected centralized systems include flat plate and concentrator PV power stations connected both to main and to diesel grid systems, with their own substation. These include several large building rooftop systems. 2. A variety of small modules (< 40 Wp) are also used extensively around Australia, typically for consumer appliances and lighting.

Table 4.8: Solar market in Australia to 2020

Year	MW	MWh	tCO_2	Market Volume in US$m	Jobs
2003	7	28,266	16,960	25	201
2005	9	52,290	31,374	32	289
2010	107	436,751	262,051	270	3,303
2020	2,597	13,214,057	7,928,434	3,540	79,786
Total 2000 to 2020	**9,331**	**46,947,838**	**28,168,703**		

PART FOUR: THE SOLAR FUTURE

Renewable Remote Power Generation Program

The Renewable Remote Power Generation Program 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", and selected large projects will be able to claim up to 70% of their costs. PV makes up 91% of the installed capacity. The amount allocated to water pumping is limited to 5% of the total funds provided to each state. Seven RRPGP Programs are currently operating in five states, with an eighth, the Indigenous Community Support Program (Bushlight), managed federally across several states.

Program funds total AUS$ 264 million and are allocated on the basis of the relevant diesel fuel excise paid in each state or territory by public generators in financial years 2000/01 to 2003/4. By the end of 2003 AUS$ 25.5 million had been allocated to small projects and a further AUS$ 14.7 million to major projects. AUS$ 5.9 million had also been allocated to industry support activities, including test facilities, standards and certification. By the end of 2003, 2.13 MWp of PV had been installed in small systems and a further 0.28 MWp in utility-operated diesel grid systems. Although the program extends to 2009/10, it is likely the funds will have been exhausted by then. Currently some rural communities have difficulty finding matching funding.

Photovoltaic Rebate Program

The PVRP initially provided AUS$ 31 million over a three and a half year period to meet up to half the PV system capital costs for both grid and off-grid installations. Although it was recently extended with another AUS$ 5.8 million, the program will finish by the end of 2004 or mid 2005.

In 2003, 1,025 systems (1.37 MWp) were installed, with AUS$ 6.03 million allocated in rebates. This brought the program total to more than 4,800 systems (5.4 MWp), with rebates of AUS$ 26.4 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 capacity be increased from 10 kW to 100 kW*
- *that a review 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 Paper the government ruled out any increases to the size or duration of the target, and no reference was made to the other recommendations.

Solar Cities

Announced in the 2004 Energy Paper, the Solar Cities program will provide AUS$ 75 million for three urban areas to directly support uptake of PV and solar hot water, as well as energy efficiency and efficient pricing signals. These arrangements would include time-of-day pricing, interval metering and cost-reflective buy-back arrangements for electricity. They aim to capture the benefits of PV in matching peak demand, thus reducing transmission and generation costs.

Expressions of interest will be called in late 2004, with selection of the Solar Cities some time after that. However, although this program should provide valuable information for the PV industry, it is not a suitable replacement for (an ongoing) PVRP, as it focuses on only three regions, will not start until 2006-7, runs for only about seven years and will not provide long term national market transformation.

Policy Outlook

With the PVRP to be terminated, the recommendations of the MRET Review unlikely to be implemented and the Solar Cities program providing only limited localised support, the RRPGP will be the only significant market development program operating in Australia. However, it applies only to off-grid and fringe-of-grid systems, and the federal government plans to remove excise on diesel fuel, making it hard to compete with diesel generators. It is likely therefore that the Australian PV industry will enter a slump, affecting local installation more than manufacturing, since in 2003, 64% of locally manufactured cells and 49% of modules were exported.

What the industry needs is long-term market support to provide certainty. Current policies are likely to result in a boom/bust cycle. Research into the capability of PV to reduce exposure to peak loads on the distribution network and exposure to peak generation prices is needed. The industry development and employment creation potential needs to be recognised, especially for exports. Administrative barriers are not particularly problematic. The most significant barrier to market expansion is high capital cost.

The Role of Utilities

The attitudes of electricity retailers and grid network operators (DNSPs) to PV vary. Although most are generally supportive, dealing with small systems is not cost-effective, and sometimes given low priority. Some DNSPs have high barriers to entry, such as connection costs that are much higher than the costs they actually incur, while others provide connection (including metering) for free. Some retailers will not reimburse system owners for electricity exported to the grid (in excess of imports) and claim all Renewable Energy Certificates (RECs), while others pay more for exported than for imported electricity and guarantee to pay the system owner the market price for all RECs (currently offering AUS$ 37/MWh).Some research is currently being carried out into the benefits that PV has for DNSPs and retailers in terms of reducing exposure to peak loads on the distribution network and exposure to peak generation prices. It is hoped that the Solar Cities program will help quantify these benefits.

The Australian PV Industry

Cell production increased in 2003 from 20.5 to 26.3 MWp and module production from 7 to 9.6 MWp. Cell production capacity also increased to 33.5 MWp by the end of 2003, with a further 5 MWp capacity in concentrator systems.

BP Solar currently operates a 35 MWp facility in Sydney, and plans to expand this to 40 MWp in 2004/05. Origin Energy is currently building a $ 20 million 5 MW manufacturing plant in South Australia using Australian National University developed Sliver® cell technology. If it meets design objectives it will be expanded to 25 MW. Sliver® cells are long, narrow, highly efficient and bifacial and enable up to 12-fold (92%) savings in silicon feedstock and 25-fold (97%) savings in wafers needed per MW of module production. Because of these advantages they will significantly reduce the costs of PV.

Pacific Solar had plans to build a 20 MW Crystalline Silicon on Glass PV factory in 2005, but decided to move it to Germany because of the lack of a local market.

In 2003, 64% of cells and 49% of modules were exported, while around 30% of modules installed in Australia were imported. The industry has a net value of around AUS$ 164.8 million. This is made up of AUS$ 95.1 million from the domestic market, AUS $ 106.26 from exports, but less AUS$ 36.56 for imports of wafers and module components. These values do not include education, R&D, ongoing operation and maintenance or BOS exports.

Australian PV Market Status

Installed capacity has increased from 7.3 MWp in 1992 to 45.6 MWp in 2003, with 6.5 MWp installed during 2003 (4.8 MW off-grid, 1.7 MW on-grid). Installations are dominated by off-grid applications (87% of the total), with 57% industrial and 30% residential. The cumulative total to 2003 is made up of off-grid domestic (30%), off-grid non domestic (57%), grid-connected distributed (10%) and grid-connected centralised (3%). The size of systems installed through government support programmes (see page 38) have remained steady, with grid-connected systems averaging around 1.5 kWp and off-grid systems around 1.1 kWp. Some larger systems are being installed.

Off grid systems include a 56 kWp system installed at the remote Aboriginal community of Bulman in 2002 at a cost of AUS$ 0.9 million and a 225 kWp system installed at a national park tourist facility in Kings Canyon in 2003 at a cost of AUS$ 2.9 million.

Grid-connected systems include:

- *The Athletes' Village which formed part of the Sydney 2000 Olympics complex, now part of the new Sydney suburb of Newington at Homebush. All 665 permanent houses have 1 kW grid-connected systems.*
- *Kogarah Town Square, a recent development of residential, commercial and retail spaces, public library and car parking, has a total of 165 kWp of grid-connected PV, made up of 148.6kWp of amorphous laminate, and 11.4kWp of transparent glass PV.*
- *Singleton Solar Farm, a 400 kW array built in 1998.*

In the Greenpeace/EPIA scenario, concerted action by industry and government would lead to a strong solar PV industry in Australia, with an increase in production capacity to approximately 100 MWp by 2010. By 2020 the market volume would reach 2,500 MWp. Almost 53,000 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 Australian 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 programmes

There are currently three main market development programmes provided by the government for PV in Australia: the Renewable Remote Power Generation Program (RRPGP), the Photovoltaic Rebate Program (PVRP) and the Mandatory Renewable Energy Target (MRET). The latter sets a national requirement for power companies to source an increasing proportion of their electricity from renewable energy. Some regional authorities provide top-up funds. A Solar Cities program, announced in June 2004, is expected to begin in 2005.

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.

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.

All retailers currently pay the same tariff for imported and exported electricity, except for Australian Inland Energy, which pays 1 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.

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 4.9 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 well over 5 GWp by 2010, with electricity output of about 5 TWh. By 2020 it will have exceeded 30 TWh, covering 2.5% of Japan's electricity demand and with an installed capacity of over 30 GWp. Over the next 15 years the number of jobs created by the PV industry in installation and maintenance services would be more than 126,000.

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. 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 last year. The subsidy for home applications, however, has been decreasing and is scheduled to end in fiscal year 2005. If the promising home application market is to continue to flourish, either the current support scheme should be continued 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 4.9: Solar market in Japan to 2020

Year	MW	MWh	tCO_2	Market Volume in US$m	Jobs
2003	223	529,400	317,640	757	6,868
2005	321	1,117,592	670,555	956	9,892
2010	1,260	4,958,027	2,974,816	2,748	38,715
2020	4,085	32,568,550	19,541,130	4,826	126,263
Total 2000 to 2020	**31,309**	**197,975,063**	**118,785,038**		

OECD North America

Growth rates envisaged in this scenario for the North American PV market are the most moderate in the industrialised world. This is a result of the energy policy adopted by the US government, which is not presently fostering the development of PV in a serious way. Even though solar irradiation and the operating conditions in the large North American land mass are extremely favourable to PV, growth rates are expected to be moderate. Canada does not play a significant role as yet, with a total installed capacity of 7 MWp and a growth in 2000 of just 1.3 MWp.

The importance of the US market for the global PV industry will therefore decrease if there is no shift in policy within the next few years. While the annual solar power markets in OECD Europe and OECD Pacific are expected to grow by 30% per year and exceed 8 GWp by 2020, the market in OECD North America will by then only be around 0.8 GWp. On the other hand, a change in the US approach, particularly over climate change, could dramatically improve future prospects.

CASE STUDY: SOLAR GENERATION IN THE UNITED STATES

Because of the key position of the US in the future solar PV market, two different scenarios have been calculated. The first assumes "business as usual", with an annual growth rate of 20% up to 2020. The second "take-off" scenario is based on the assumption that the US market will make a determined attempt to catch up with its European competitors.

The first table below shows the expected outcome if the United States continues with its present lukewarm approach to PV support. As a result of serious budget cuts and repeated delays in PV support programmes, the annual growth rate is expected to remain at 20% throughout the scenario. If the US government doesn't invest in PV, then the country's market will be five times smaller in 2005 than the EU's. By 2010 the US solar market would be even smaller than Germany's. By 2020 the US would have a world market share of just 2%.

If the US government decided to establish a nationwide support scheme similar to those operating in Germany or Japan, then a different market development would be possible (see Table 4.11). This "take-off" scenario assumes that the US domestic market will develop along the lines of Europe, with an ambitious target for 3,500 MWp 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 USA, and the industry would create more than 220,000 jobs.

Government Policy and Programmes

The conclusion of the scenario for US federal and state energy planners is that if the government decided to support the industry with a national programme, such as a reducing fixed rate tariff, then the market growth could be equal to that of Europe. The US PV industry would then be among the world leaders.

Table 4.10: Solar market in the US to 2020 (business as usual)

Year	MW	MWh	tCO_2	Market Volume in US$m	Jobs
2000	22	41,940	72	86	660
2005	55	658,810	365,535	164	1,688
2010	136	1,724,086	893,494	299	4,200
2015	339	4,414,975	2,207,225	551	10,451
2020	843	11,110,766	5,476,208	1,017	26,006

Table 4.11: Solar market in the US to 2020 (take-off scenario)

Year	MW	MWh	tCO_2	Market Volume in US$m	Jobs
2003	63	514,440	115,560	214	1,934
2005	91	799,042	295,186	270	2,797
2010	521	3,615,470	1,938,102	1,137	16,041
2020	7,187	57,093,702	33,133,738	8,491	221,141
Total 2000 to 2020	30,209	239,422,451	136,257,233		

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 which 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 is 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.

Various PV incentives have been introduced, including a 50% capital subsidy for solar home systems and subsidies of 50% and 67% respectively for isolated and grid-connected solar power projects which do not exceed a capital cost of $ 5.50/Wp. A solar lantern subsidy is also available of up to $ 42.

The Greenpeace/EPIA scenario is based on an average growth rate between 2000 and 2020 of 35%. By 2020, the Indian PV market would have a market volume of more than $ 5 billion a year. If all the systems installed were manufactured in India itself this would add a further roughly 80,000 jobs to the 112,870 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 Program. 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 which should specify priorities and further support measures.

Total installed capacity of PV in Thailand is currently about 5 MW, with just 1 MW installed during 2003. To build up a stable and self-supporting solar PV market by 2010 a support programme is therefore needed. The Greenpeace/EPIA scenario

Table 4.12: Solar market in India to 2020

Year	MW	MWh	tCO_2	Market Volume in US$m	Jobs
2003	11	56,644	33,986	44	344
2005	16	97,891	58,735	55	496
2010	90	446,977	268,186	225	2,747
2020	3,678	16,634,071	9,980,443	5,013	112,870
Total 2000 to 2020	**11,792**	**54,225,040**	**32,535,024**		

Table 4.13: Solar market in Thailand to 2020

Year	MW	MWh	tCO_2	Market Volume in US$m	Jobs
2003	3	10,563	6,338	13	104
2005	8	27,016	16,209	26	233
2010	34	159,678	95,807	86	1,047
2020	685	3,421,923	2,053,154	933	21,046
Total 2000 to 2020	**2,598**	**12,995,467**	**7,797,280**		

is based on a target for 120 MW installed capacity by 2010. With a market growth rate of 35% between 2010 and 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 1,000 jobs in installation and maintenance. By 2020 more than 20,000 jobs could be expected in installation and maintenance, with additional potential in manufacture and development.

Government Policy and Programmes

The Thai government should 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 ARGENTINA

Although significant regional and seasonal differences exist, Argentina has a huge natural potential for solar energy use. The central region of the country has an insolation of about 1,600 kWh/m2/year, an excellent resource compared with most regions of Europe. This potential remains largely untapped, however, with installed capacity presently around 5 MWp.

So far, solar power use in Argentina has been mainly in isolated areas, for example for telecommunications, houses without electricity supply, water pumping, cathodic protection and sign posting. Rural electrification programs have been supported with funding from the World Bank and the Global Environment Facility. Despite activity in this area, however, there still remains a huge un serviced rural market.

According to the Argentinian Energy Department, 5% of the population is still without an electricity supply, representing about 1.8 million people or some 300,000 homes. At least 2,000 rural schools are estimated to operate without electricity.

The Energy Department recently relaunched the rural electrification programme called PERMER (Renewable Energies Program for Rural Markets) funded by the World Bank and by subsidies from the GEF. The aim is to invest a total of $ 59 million, with additional grants from the national and provincial governments.

There has been no experience of PV installations connected to the grid in Argentinian cities. Regulatory barriers and the lack of specific incentives to promote solar power have so far inhibited this development. A pioneering effort to spread the technology among architects and designers was made at a 1999 seminar in Buenos Aires, resulting in a design competition to develop examples of PV integration into buildings and urban spaces.

In April 2001, Greenpeace unofficially connected the first photovoltaic generator to the grid in Argentina. This technically illegal installation sparked an ongoing discussion about the technological basis for a future national regulation allowing connection of small scale renewable energy-powered equipment to the grid.

In the same year Argentina suffered a significant economic crisis, with an extraordinary depreciation of its currency, resulting in the costs of PV systems rising threefold. For this reason the scenario for Argentina, originally compiled before the economic crisis, has been changed. To build up a solid ongoing solar PV market in Argentina it is clear that a national support programme is needed.

The Greenpeace/EPIA scenario is still based on a target of 90 MWp of installed capacity by 2010. From then on, even with a moderate growth rate of 30% between 2010 and the end of the scenario period, the market in Argentina looks very promising. With solid development over the succeeding years, the country could achieve a 10% share of the Latin American market. Within ten years this would create more than 3,800 jobs in installation and maintenance. By 2020 more than 14,000 jobs could be expected in installation and maintenance, with additional potential in manufacture and development.

Table 4.14: Solar market in Argentina to 2020

Year	MW	MWh	tCO_2	Market Volume in US$m	Jobs
2003	1	6,497	3,898	5	41
2005	2	10,802	6,481	6	50
2010	33	125,341	75,205	84	1,031
2020	462	2,723,744	1,634,246	630	14,209
Total 2000 to 2020	1,912	10,802,924	6,481,754		

Government Policy and Programmes

A national regime for grid connected renewable systems, including net metering and low interest credit for home solar systems, is badly needed. This could be financed by switching current subsidies for nuclear power to solar systems. A national law needs to be passed in the National Congress to establish a target for 8% of national electricity to come from renewables by 2013 - a target already included in the government's International Action Plan presented at Renewables 2004 in Bonn. Clean energy projects such as solar PV should also be made a priority for CDM investment under the Kyoto Protocol mechanisms.

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. 80% of the Chinese population lives in rural areas, and 30 million people have no access to electricity. In 1998 the government announced the linking of three state agencies involved in renewable energy - the Ministry of Science and Technology, the State Development and Planning Commission and the State Economic and Trade Commission - to work together on a programme for New and Renewable Energy Development in China up to 2010. Included in their targets is for the equivalent output from 4.67 million tons of coal to be produced by solar energy.

The same three organisations have also launched a PV programme know as the "Sunlight Program". Operating until 2010 this is expected to:

- *Upgrade the country's manufacturing capacity*
- *Establish large scale and PV-hybrid village power demonstration systems*
- *Promote home PV projects for remote areas*
- *Integrate grid-connected PV projects*

Besides these initiatives, a Global Environment Facility-World Bank renewables development programme is scheduled to support the installation of 200,000 solar home systems with a total capacity of 10 MW. China had already installed a generation capacity of about 42.5 MWp by the end of 2002, distributed as follows:

Table 4.15: PV in China by application	Installed capacity by end of 2002
Rural electrification	31.0 MW_{peak}
Telecommunications	5.0 MW_{peak}
Consumer Goods	6.0 MW_{peak}
Grid-connected systems	0.5 MW_{peak}

Newly installed capacity in China during 2004 is expected to reach approximately 35 MWp. Within the programme "Song Dian Dao Xiang" (sending electricity to villages) alone, it is planned to install 100 - 150 MWp over the period 2005 to 2010. This programme is completely initiated and funded by the Chinese government.

In parallel to this, the Chinese PV industry is also growing. At the 19th European Photovoltaic Solar Energy Conference and Exhibition in June 2004, 32 companies and organisations from China were represented. Three years before, only two companies were present.

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.

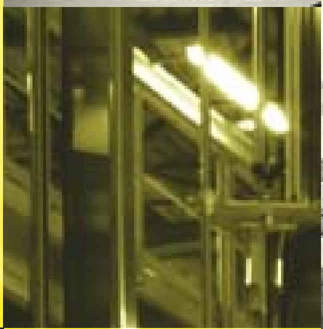
In 2020 the Chinese solar PV market could be the third largest in the world, creating nearly 230,000 jobs in installation alone. The total energy output in 2020 would be 31.3 TWh, the equivalent of 31 coal-fired power plants. This market development needs a strong and long-term support programme.

Government Policy and Programmes

As well as providing incentives to developers and manufacturers of solar PV systems, the Chinese government should introduce legislation which both encourages renewable energy sources and removes all institutional, market and policy barriers to the operation of PV projects. The Sunlight programme should be expanded in order to play a more important role. China should also look towards more pro-active involvement from foreign investors.

Table 4.16: Solar market in China to 2020

Year	MW	MWh	tCO_2	Market Volume in US$m	Jobs
2003	25	152,750	91,650	98	770
2005	44	255,125	153,075	150	1,348
2010	181	948,115	568,869	456	5,560
2020	7,444	31,370,752	18,822,451	10,147	228,450
Total 2000 to 2020	23,900	103,731,754	62,239,053		


PART FIVE

WINNERS AND LOSERS IN THE SOLAR GENERATION



PART FIVE: WINNERS AND LOSERS IN THE SOLAR GENERATION

The rapid rise in the price of crude oil in 2004 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. Production of "cheap" oil 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 run away 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 seeing numerous countries having to rapidly reduce their dependence on imported oil and gas. This abrupt transition will particularly be accompanied by significant pain in those countries which 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 now 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 give rise to both 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.

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.

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 rapid uptake of solar electricity in Germany has been the result of the introduction of a national feed-in tariff for solar electricity which 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 which makes the installation of a solar electricity system so attractive. One other 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 on all electricity users. This ensures that the 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 which 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 foremost 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. Amongst 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 which 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 which, 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 which 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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