2 MILLION JOBS

SOLARGENERATION

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

CONTENTS

NOTE
THE CURRENCY USED IN THIS REPORT IS MAINLY THE US DOLLAR. WITH THE EURO IN SOME SECTIONS ON EUROPEAN COUNTRIES. THE TWO CURRENCIES HAVE A SIMILAR VALUE.



FOREWORD

Solar energy is a success story. It already supplies electricity to several hundred thousand people around the world, provides employment for over ten thousand and generates business worth more than $1 billion dollars. In the future, the pace of change and progress could be even more rapid as the solar industry unlocks its hidden promise.

The benefits of solar power are compelling: environmental protection, economic growth, job creation, 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 irradiated from the sun to the earth's surface is enough to provide more than 10,000 times the annual global energy consumption. 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, offering far greater control to individual consumers.

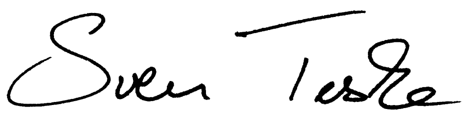
A solid international consensus now clearly states that business-as-usual is no longer an option if we are to prevent dangerous climate change, and the world must move into a clean energy economy. Solar power is a prime choice in developing an affordable, feasible, global power source that is able to substitute for fossil fuels in all climate zones around the world.

Greenpeace and the European Photovoltaic Industry Association (EPIA) have produced this report 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 one billion people within two 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 consumer 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.

Reports are a useful guide, but it is people who change the world by their action. 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.

Dr. Murray Cameron
Chief Executive
European Photovoltaic Industry Association (EPIA)
September 2001



Sven Teske, B.Sc
Renewable Energy Campaign
Greenpeace

EXECUTIVE SUMMARY

Global Status of Solar Photovoltaics

The solar electricity market is booming. In the year 2000 the cumulative installed capacity of all solar photovoltaic (PV) systems around the world passed the landmark figure of 1,200 Megawatt peak (MWp). At the same time global shipments of PV cells and modules have been growing at an average annual rate of 33% since 1996.

Such has been the growth in the solar electricity industry that it is now worth more than an annual $1 billion in sales. 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 support and promotion frameworks being put in place in a number of countries, notably Germany and Japan.

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 is just the start 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 retail areas. At the same time, there is a need to transmit to as wide an audience as possible the message that solar electricity will bring socio-economic and environmental benefits to regions which proactively encourage its uptake and the development of a local industrial base.

Solar Generation: The impact of solar electricity on the lives of consumers and job seekers born today

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

The Scenario for the year 2020, together with an extended projection forward to 2040, is based on the following 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 worldwide up to 2009 is projected to be 27%, then rising to 34% between 2010 and 2020 to take into account significant openings in markets in developing countries. In Europe, the growth rate until 2009 is consistent with the EPIA Industry Roadmap scenario.

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 27,000 Terawatt hours by 2020.

Carbon dioxide savings: Over the whole scenario period it was 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% was assumed along with a very conservative lifetime of 20 years for PV modules.

The scenario is also divided in two ways – into the four main global market divisions (consumer applications, grid-connected, remote industrial and off-grid rural), and into the regions of the world as defined in projections of future electricity demand made by the International Energy Agency. These regions are OECD Europe, OECD Pacific, OECD North America, Latin America, East Asia, South Asia, China, the Middle East, Africa and the Rest of the World.

Solar Generation: Key Results of the EPIA/Greenpeace Analysis

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

Global Solar Electricity Output in 2020: 276 TWh =

30% of total demand in Africa

10% of total demand in OECD Europe

1% of total global electricity production

Global Solar Electricity Output in 2040: 9,113 TWh =

26% of total global demand more than the combined demand in OECD-Europe and OECD-North America in 1998

Detailed Projections for 2020 :

PV systems capacity	207 GWp
Grid-connected consumers	82 million worldwide
	35 million in Europe
Off-grid consumers	1 billion worldwide
Employment potential	2.3 million full-time jobs worldwide
Investment value	$75 billion per annum
Cost of solar modules	Level of $1 per Wp achieved
Cumulative carbon savings	664 million tonnes of CO_2

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 276 Terawatt hours 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 30% of the entire continent of Africa. Put another way, this would represent the annual output from 75 coal-fired power plants.

Global installed capacity of solar power systems would reach 207 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 number of people by then generating their own electricity from a grid-connected solar system would reach 82 million. In Europe alone there would be roughly 35 million people generating solar electricity with a grid connected solar system.

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. 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 27,000 to 35,000 TWh, the solar contribution would equal 26% 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 253 MWp in 2000 to more than 50,000 MWp in 2020.

For the job seekers of the 2020 generation, this will be a major contribution towards their employment prospects. On the assumption that more jobs are created in the installation and servicing of PV systems than in their manufacture, the result is that by 2020, around two 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 166 million tonnes. This reduction is equivalent to the emissions from all 44 million cars currently operating in Germany, or 75 coal-fired power plants. Cumulative CO_2 savings from solar electricity generation between 2000 and 2020 will have reached a level of more than 664 million tonnes, equivalent to two-thirds of Germany's total CO_2 emissions in 2000.

Policy recommendations

In order to supply more than one billion people with solar electricity by the year 2020, and achieve an electricity share of almost 26% by 2040, a major shift in energy policy is needed. Experience over the past few years has demonstrated the effectiveness of joint industrial and political commitment in 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: Stabilisation of the annual world PV market at a level of 1GWp+ by 2006 will only be achieved through the extension of policies to regulate production standards, 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 regulatory barriers to the take-up of solar power – and the subsidies available to fossil and nuclear fuels which currently penalise renewable sources, must be removed.

- Thirdly: A variety of legally enforced mechanisms must be implemented which secure and accelerate the new market for solar photovoltaics.

Our goal now must be to mobilise the necessary industrial, political and end-user commitment to this technology and, more importantly, the service it provides. We must redouble our efforts to ensure that the population born today receives from all the socio-economic and environmental benefits that solar electricity offers. The Solar Generation should know no north/south divide. It should be an inclusive generation bringing together by 2040 a significant fraction of the world's population in both industrialised and developing countries – a generation supplied by an industry driven by customer needs and the ability of a sophisticated global market to meet those needs.

PART ONE: SOLARBASICS

The Solar Potential

There is more than enough solar radiation available around the world to satisfy a vastly increased demand for solar power systems. The total amount of energy irradiated from the sun to the earth's surface is enough to provide for annual global energy consumption 10,000 times over. Energy from the sun's light alone is enough to produce an average 1,700 kWh of power annually on each square metre of land.

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.

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 1.1 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 and assumes that the panels are installed at the optimal angle to the sun required at different latitudes.

The most recent study of the potential for PV in the OECD (industrialised) countries is "Solar Electricity in 2010", published in 2001 by the European Photovoltaic Industry Association. This shows that grid-connected PV rooftop systems, the most dynamic growth area in the market, have the potential to generate an average of 16% of final electricity consumption across the OECD. This is more than the 1996 contribution from hydro power (see figure 1.3).

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 found in, amongst other things, 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 can even generate electricity on cloudy days. Depending on the density of the clouds a PV system still generates 20-50% of its maximum electricity output. Due to the reflection of sunlight, days with only a few clouds can even result in a higher energy yield than days with a completely blue sky.

Figure 1.1: Global variations in irradiation

Source: Gregor Czisch, ISET, Kassel, Germany

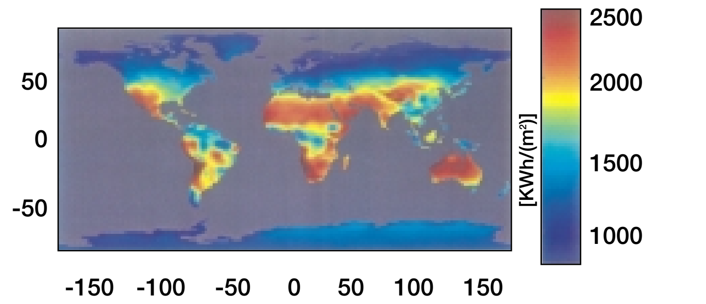


Figure 1.2: Energy potential from PV around the world

Source: Gregor Czisch, ISET, Kassel, Germany

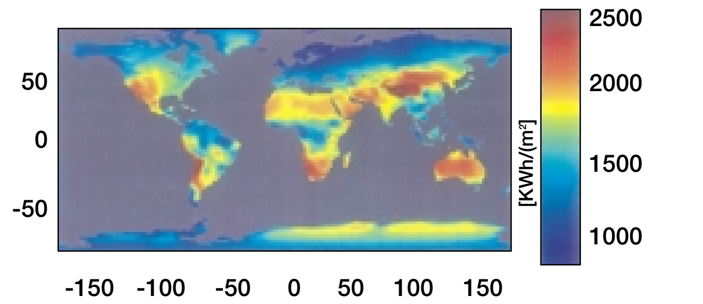


Figure 1.3: Potential PV Contribution to OECD Electricity in 2010

Source: "Solar Electricity in 2010", EPIA, 2001

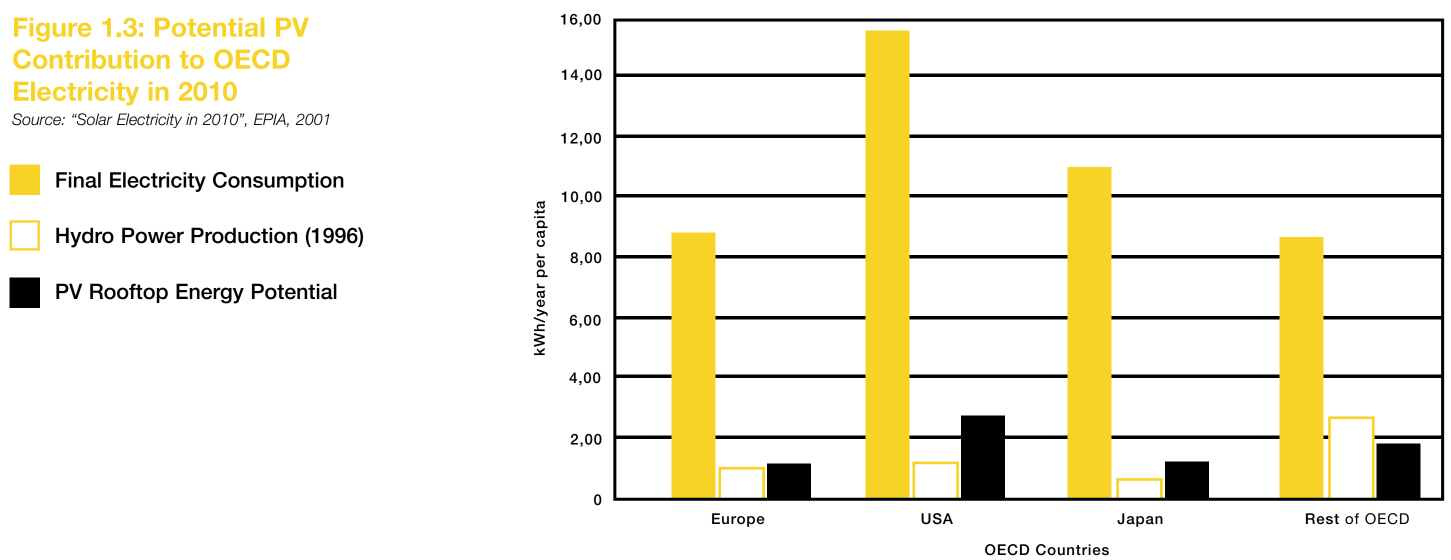


Table 1.1: Module and cell efficiencies

Source: International Energy Agency (IEA) Photovoltaic Systems Programme, 2000

Type	Typical module efficiency (%)	Max. recorded module efficiency (%)	Max. recorded laboratory cell efficiency (%)
Single crystalline cell	12-15	22.7	24.7
Multicrystalline silicon	11-14	15.3	19.8
Amorphous silicon	5-7	-	12.7
Cadmium telluride	-	10.5	16.0
CIS	-	12.1	18.2

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.

• 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 thick **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 (84%) has so far involved the former, whilst future plans centre on the latter. Thin film technology is expected to dramatically increase its share the market for solar panels on buildings because of its advantages in terms of weight, durability and attractive appearance.

Crystalline silicon

Crystalline silicon is still the mainstay of most power modules. Although 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 13-14% efficiency. The theoretical limit for crystalline modules approaches 30%.

Thin films

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.
Three types of thin film cell are likely to be of increasing commercial importance over the next few years. These are the amorphous silicon cell, most probably in a double junction structure, the copper indium diselenide/cadmium sulphide hetero-junction cell and the cadmium telluride/cadmium sulphide hetero-junction cell. All of these have active layers in the thickness range 1-10 microns, and all are manufactured by processes which are capable of large volume, low cost production.

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.

Spherical solar technology uses minute silicon beads bonded to an aluminium foil matrix. This offers a big cost advantage because of the reduced need for silicon. The technology is still a long way from commercial production, however.

The **organic dye solar cell** invented in 1991 by the Swiss physicist, Michael Grätzel, still has low efficiencies and shows a poor long term stability. In theory, however, it is easier to manufacture than other solar cells.

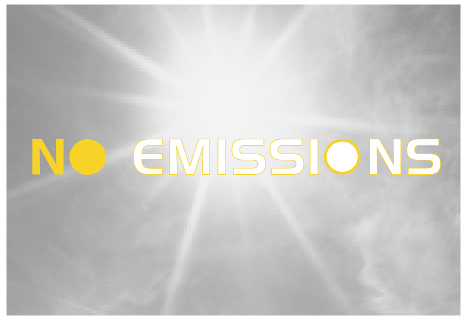
These examples demonstrate that there is considerable momentum within solar cell R&D in order to meet the range of applications demanded by a growing PV market.

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 strong, reliable and weatherproof. Module producers usually give a performance warrantee of 20 years on 80% of the rated module power.

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



When a PV installation is described as having a capacity of 3 MWp(eak), this refers to the maximum output of the system under standardised operating conditions, allowing comparison between the expected production from different systems. In northern Europe a 1.2 kWp rated solar array, covering about 10 square metres, would produce enough power for roughly one third to a half of a typical household's electricity requirements.

Inverters

Inverters are used to convert the direct current (DC) power generated by a PV array into alternating current (AC) which is compatible with the local electricity distribution network. This is essential for grid-connected PV systems. The inverter also often includes elements to protect the system against instability in the grid connection.

Components for Stand-alone PV Systems

Most stand-alone (off-grid) PV systems contain a battery, commonly of the lead acid type, in order to store the energy for future use. This is usually 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

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

Grid Support

This type of 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. It is ideal for use in areas of unreliable power supply.

Off-Grid

Completely independent of the grid, the system is directly connected to a battery, 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.

Hybrid System

This is a solar system that 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. This is why comparisons with conventional electricity generation – and more particularly comparison with the unit energy costs of conventional energy 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.

• 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. In the UK, for example, it has been estimated that the country's total electricity demand could be satisfied by solar arrays using only 3% of the land area.

CLIMATE CHANGE AND FUEL CHOICES

Carbon dioxide is responsible for about 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. Coal, oil and natural gas all produce carbon dioxide and other polluting gases. Nuclear power produces very little CO_2, but has other major 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 30% since industrialisation began.

- The number of natural disasters has trebled since the 1960s. The resulting economic damage has increased by a factor of 8.5.
- The seven warmest years over the last 130 were recorded during the past 11 years.
- The mass of glaciers has been halved since industrialisation began.
- Rainfall in temperate and northern latitudes has increased by 5% since 1950. Average wind speed has also increased significantly.
- Sea level has risen by 10-20 centimetres in the last 100 years, 9-12 cm of this in the last fifty.

Because of the time lapse between emissions and their effects, the full consequences of developing climate change 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 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.

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 box "Climate Change and Fuel Choices")* – during the operation of a PV system. Although indirect emissions of CO_2 occur at other stages of the manufacture, these are significantly lower than the avoided emissions.

Solar power can therefore make a substantial contribution towards international commitments to reduce the steady increase in the level of greenhouse gases and their contribution to climate change *(see box "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.

Solar power can be easily installed in remote and rural areas, places which may not be targeted for grid connection for many years. This can help reduce urban migration through the provision of essential services. 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 typical system – about 20-25 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 demonstrate, however, that present-day systems already have an energy payback time – the time taken for power generation to compensate for the energy used in production – well below their expected lifetime (3-7 years for crystalline silicon modules, depending on the solar irradiation, the cell material and the frame) For frameless thin film modules the energy payback time is already below 2 years for areas such as Mediterranean countries. With increased efficiency in the production of cells it is feasible that the energy payback time for grid-connected PV will decrease to two years or less for crystaline silicon modules and to one year or less for frameless thin film modules.

One way in which efficiency will be increased is through the production of solar-grade silicon specifically designed for the PV market, as opposed to the high quality silicon from the electronics industry currently employed.

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.

- The 1997 **Kyoto Protocol,** brokered by the United Nations, committed the world's developed countries to reduce their emissions of greenhouse gases by an average of 5% from their 1990 level. Despite continuing negotiations over the details of Kyoto, many nations have taken up this challenge.

- The **European Union** has set a target to double the proportion of energy in the 12 member states provided from renewable sources. The aim is for 12%renewable energy by 2010. This includes a specific target to achieve 3 Gigawatt peak 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).

PART TWO: THE SOLAR POWER MARKET

SOLARGENERATION

Solar power is booming. By the end of 2000 the cumulative installed capacity of all PV systems around the world had reached the landmark figure of 1,200 MWp. Shipments of PV cells and modules around the world have been growing at an average annual rate of 33% for the past four years.

Such has been the growth in the solar industry that it is now worth an annual $1 billion. Competition among the major manufacturers has become increasingly intense, with new players entering the market as the potential for PV opens.

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, even when parked. The result is a much cheaper air conditioning system than by simply using conventional 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 2000 this sector accounted for roughly 25 MWp, almost 10% of global annual production. As demand for a mobile electricity supply increases, the sector is likely to continue to grow.

Grid-connected systems

Applications

PV can be integrated into the roofs and facades of houses, offices and public buildings. Private houses are a major growth area for BIPV (Building Integrated PV), with the average capacity of domestic systems in Germany now approaching 3 kWp. In the UK, for example, it is estimated that a 2 kWp system will supply about 50% of an average household's electricity demand.

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

If PV is recognised as a natural 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, especially in countries with a high cooling load.

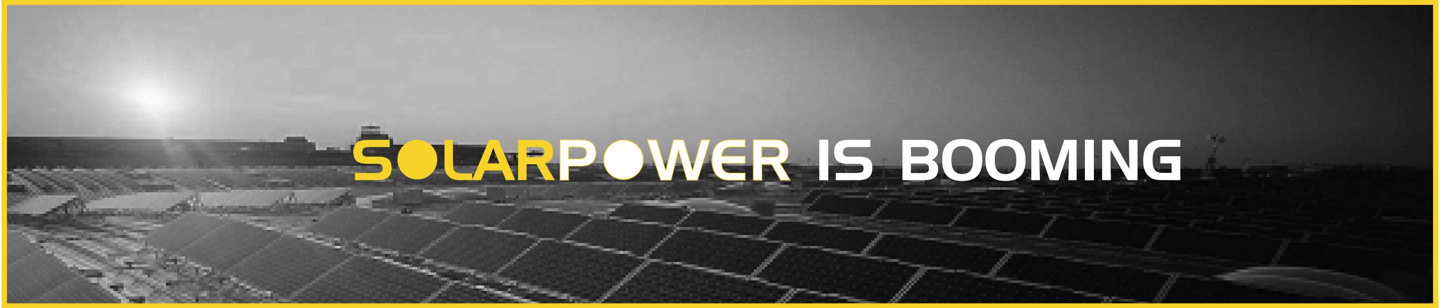
Large scale grid-connected PV arrays have not so far become a major part of the market, mainly because of the difficulty of locating enough space in built-up areas. In Europe, however, it was estimated in 1998 that the potential for integrating PV into noise barriers then planned for construction alongside motorways and railways was as high as 1,100 MWp. Sun-drenched desert regions present good opportunities in the longer term, especially with falling module prices, for instance in the south western United States, Africa and Mongolia.

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. Whilst in 1994 only 20% of new capacity was grid-connected, this had grown to 50% by 2000.

Examples of national programmes include Japan's 70,000 rooftop proposal, the 100,000 roofs initiative 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 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 grid-connected electricity. About two billion people around the world currently live without connection to the grid. 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. Electricity for lighting and medical refrigerators, water purification, etc. is critical, and more than 2 billion people in the world do not have access to electricity. Lighting enables villages to have evening literacy classes for instance, which can do a great deal to benefit the lives and economic standing of people in developing nations.

Market development

Apart from its clear social advantages, the economic justification for using PV is by comparison with avoided fuel costs, usually expensive diesel, or with the cost of extending the grid. The initial stumbling block is often the capital cost of the system for subsistence level communities. But although numerous rural development programmes have been initiated in developing countries, supported both by multi and bilateral assistance programmes, the impact has been relatively small.
One of the largest off-grid projects currently proposed is for 2 MWp to supply 150 isolated villages in the Philippines *(see box "PV Around the World").*

At their Heads of Government meeting in Okinawa, Japan, in 2000, the G8 governments, representing the world's richest nations, established task force with a remit to identify actions that can be taken to promote a step change in the supply, distribution and use of renewable energy in developing countries. The conclusions of this task force, presented to the Genoa G8 meeting in July 2001, called for concerted action to provide an additional 800 million people with access to electricity from renewable sources within the next 10 years. PV is expected to be a major component of that effort, both in terms of solar home systems, village power projects and grid-connected applications.

In April 2001 the World Bank-funded Global Environment Facility and International Finance Corporation announced a joint private equity fund with almost $30m to invest in PV in the developing world over the next ten years.

Looking for a more ambitious target, Greenpeace has called on the World Summit on Sustainable Development, being held in South Africa in 2002, to agree a programme large enough to bring renewable energy to two billion people within 10 years.
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 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. Today most of the solar electricity markets in the developing world are not very well developed. This is expected to change towards the end of this decade. The solar electricity boom in the industrialised world will support the development of solar electricty markets in the developing world.

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.

PV AROUND THE WORLD

- **A 1.6 kilometre stretch of the south-facing barrier on the busy A9 motorway near Amsterdam Schiphol airport has been fitted with 220 kWp of solar panels, providing clean energy as well as reducing the noise level for nearby houses.**
- **A 1 MWp grid-connected PV power plant in Toledo province south of Madrid is designed to track the movement of the sun, thus optimising its energy yield.**
- **A warehouse in the Swiss capital Berne has been fitted with 2000 m^2 of solar slates, making it one of the largest such roofs in the world. The 16,650 slates have a rated output of 200 kWp, all sold to customers of a local green powerscheme.**
- **For Expo 2000, 250 kWp of PV was directly linked to Hanover's light railway network, providing low voltage DC electricity for its operation.**
- **The Spanish government is supporting a $48m project in the Philippines to bring PV power to 400,000 residents in 150 isolated villages. The power will be used in homes, schools, community centres and health clinics, as well as providing lighting, irrigation and water distribution.**
- **A joint venture between Shell and the South African utility Eskom will see solar electricity brought to 50,000 rural homes in the Eastern Cape, with payment for the power being made through the "Powerhouse" credit card system.**
- **The roof of an old hangar in the city of Schwäbisch Hall, southern Germany is covered with 1,000 m^2 of solar panels with a total output of 100 kWp. The green power company Greenpeace Energy eG initiated the project and sells the electricity to its customers.**

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

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

SUPPLY SIDE MANUFACTURE

Solar 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 shipments reaching more than 110 MWp in 2000, a 46% increase over the previous year. This is followed by the US with 80 MWp and Europe with 59 MWp. During 2000, the main European producers, based in France, Germany, Spain and the Netherlands, achieved a similar growth rate to the Japanese market.

A number of other countries around the world are also developing a manufacturing base. These include Australia, India, Taiwan and China. The largest of these is India, which has a production capacity of about 12 MWp. The growth of global PV shipments over the past ten years can be seen in table 2.2 and figure 2.2. The leading manufacturers of solar cells can be seen in Figure 3. 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 into the market. In 2000, the two leading producers of PV cells/modules were Sharp and Kyocera, both Japanese companies. Japan's aim is to have 250 MW of production capacity operating by 2002.

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 2001) records 273 types of modules being produced by 58 different manufacturers in more than a dozen different countries.

An indication of the burgeoning European market came during 2001, when both BP Solar and the German company ASE announced major expansion plans. BP Solar will be building a 60 MWp production facility in Spain and ASE a similar sized factory in Germany. The $100m Spanish BP plant is scheduled to come on stream in 2002. When completed, these two outlets will together increase the present production capacity in Europe by 150%.

Table 2.1: PV cell/module manufacture - leading producers by region

This table includes most manufacturers with production capacity over 4 MWp in Europe, US and Japan, over 2 MWp in ROW.
Source: PV News, 2001

	Total shipments in 2000 (MWp)	Growth from 1999 (%)	Leading producers	Shipments in 2000 (MWp)
Europe	58.5	46	Photowatt-France (France)	14
			ASE (Germany)	10
			Isofoton (Spain)	9.5
			BP Solar (Spain)	7
			Shell (Germany/ Netherlands)	6.5
			Solar-Fabrik Freiburg (Germany)	4.6
United States	78.5	29	Siemens Solar	28
			Solarex	20
			Astropower	18
			ASE Americas	6
Japan	116.6	46	Sharp	50.4
			Kyocera	42
			Sanyo	17
Rest of the World	24.2	18	BP Solar (Australia)	6
			BP Solar (India)	5
			Sinonar (Taiwan)	3
			China	2.5

In the United States, United Solar Systems has announced plans to build a plant capable of producing an annual 25 MW of triple junction thin film cells. In Japan, Sharp announced in January 2001 that it was increasing capacity to 94 MWp, taking this year's sales revenue to $270m. Nine major companies, including Sanyo, Canon and Mitsubishi, are now involved in the Japanese PV industry, with others on the point of entry.

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 schemes like the German solar roof programme, supported by both premium price payments and cheap loans (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. Following introduction of the Renewable Energy Law in April 2000, production of modules is expected to double this year (2001). According to the German Solar Energy Association, there are currently plans to increase Germany's industrial capacity to almost 160 MW of silicon solar cells, more than 150 MW of crystalline silicon modules, and more than 9 MW of thin film modules. In a few years' time this could turn the country into a net exporter.

Manufacturing and Operating Costs
The cost of manufacturing both solar cells and modules has been falling steadily. On average, the price of modules has fallen by 5% per annum over the last 20 years.

The current capital cost of installing a PV system ranges from $5/Wp to $12/Wp, giving life-cycle costs for PV generated 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.

An indication of the savings which can be made by using solar power in off-grid situations can be seen from an analysis of the relative costs of a remote industrial diesel/ battery system and a system where PV supplies 75% of the load. Over a 1 year reduced battery lifespan, the PV input reduces the cost of the system by almost a half, and even over the normal lifespan of the diesel unit and battery the cost is reduced by about 25%.

The grid-connected market must still depend for the moment, however, on government incentive programmes. This situation is expected to change as the PV market becomes increasingly self-sustaining, with expanding market sizes in all sectors. As with any technology the economies of scale 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. The correlation between the increase in annual shipments and cost reduction for PV systems can be seen in figure 2.3.

As a consequence of falling PV system prices the cost per kWh of solar electricity is decreasing as well, although this figure is also dependent on the degree of solar irradiation. High solar irradiation results in a higher electricity yield per installed kWp of system capacity.

A Greenpeace report published in 1999 from financial services company KPMG concluded that the price of solar power would become economic in building-integrated situations if the scale of production of solar cells increased to a level of 500 MWp per year. The investment required was about $434 million. On top of this was the investment ($136 million) needed to build a plant for the production of solar grade silicon. This investment was equivalent then to just half a per cent of the money being spent by oil companies on exploration and production.

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 assembly of the unit.

- As larger PV cell and module factories come into operation, the degree of **automation in the production process** is increasing. Both ASE and BP Solar have announced plans for the construction of fully automated 60 MWp plants, for example. Bearing in mind that the 1999 production capacity in Europe was just 80 MW, and 160 MW worldwide, these new larger units offer the potential for 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. The resulting saw slurry contains roughly the same amount of silicon as needed for the actual wafer. 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 ASE at one of its factories.

- Research efforts are focused on reducing the amount of incidental light reflected back by silicon – from the present 30% to less than 5%. This involves applying an anti-reflection coating to the surface and texturing it in the form of small pyramids to **improve light capture**.

- **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.

Figure 2.1: Top producers of PV cells/modules in 1999/2000

Source: "The World Photovoltaic Market 2000", PV Energy Systems

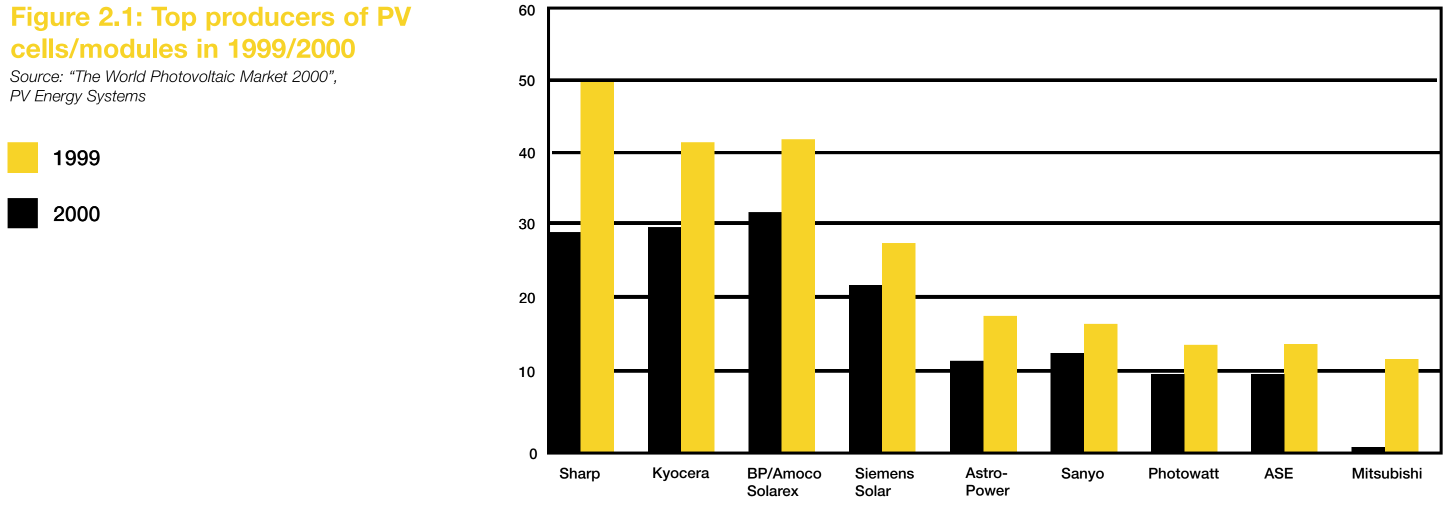


Table 2.2: Growth in worldwide PV shipments

Source: "Solar Electricity in 2010", EPIA, 2001

Region	**Annual Shipments (MWP)**									
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Rest of world	5.4	5.1	5.0	5.9	6.6	9.4	9.4	18.7	20.5	29.0
USA	16.8	18.1	22.0	25.6	34.2	39.4	51.7	53.7	63.3	80.0
Japan	19.3	18.3	16.8	16.8	17.2	21.0	35.0	49.1	80.0	110.0
Europe	13.0	16.2	16.8	21.7	20.5	19.3	30.0	31.2	37.6	59.0
Total (MWp)	**54.5**	**57.7**	**60.6**	**69.8**	**78.5**	**89.1**	**126.1**	**152.8**	**201.4**	**278.0**
Cumulative (MWp)	**313.5**	**371.2**	**431.8**	**501.7**	**580.1**	**669.2**	**795.3**	**948.1**	**1149.5**	**1427.5**
Annual Growth	**5.1%**	**5.8%**	**5.1%**	**15.3%**	**12.3%**	**13.5%**	**41.6%**	**21.1%**	**31.9%**	**38.0%**

Table 2.3: Growth in worldwide PV shipments

Source: "Solar Electricity in 2010", EPIA, 2001

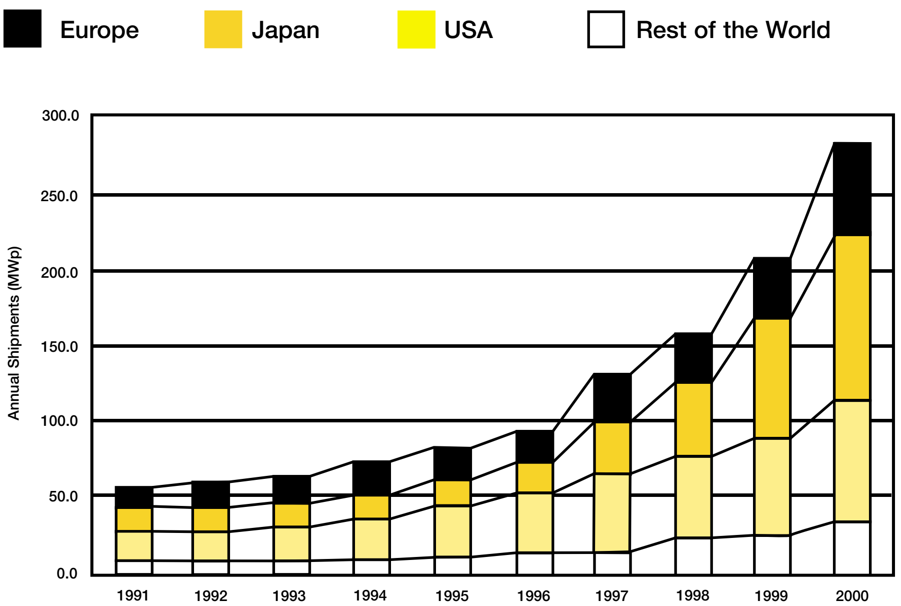
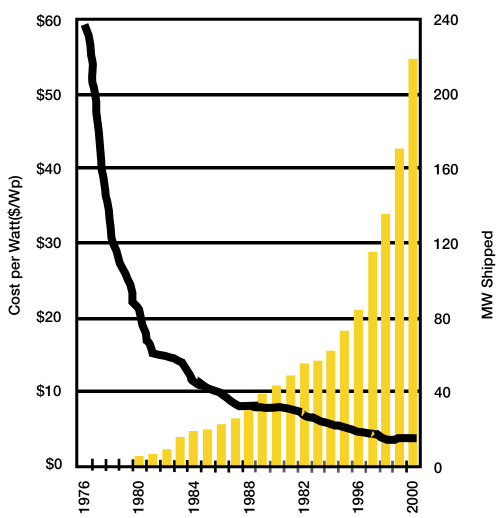


Figure 2.4: The falling cost of PV as shipments increase

Source: BP Solar



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 in particular 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

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.

Third globally behind Japan and the US, Germany's current installed capacity 113 MWp has largely resulted from the high growth rate of its building-integrated market, from small units through to megawatt rooftop systems. More than 44 MWp was installed in 2000 alone. One estimate is that the country could achieve a figure of 438 MWp by 2004.

In the background is the German Social Democrat/Green government's Kyoto-led commitment to reduce its emissions of greenhouse gases by 21% between the years 1990 and 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 1991 Renewable Energy Feed-In Tariff Law and the 2000 Renewable Energy Law. One result is that the wind energy industry has seen a capacity of over 7000MV installed, representing roughly 2.5% of electricity supply, and an estimated 30,000 jobs created in less than a decade. The German solar industry now foresees 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 €9/Wp and produced an average 700 kWh per kW installed over the year.

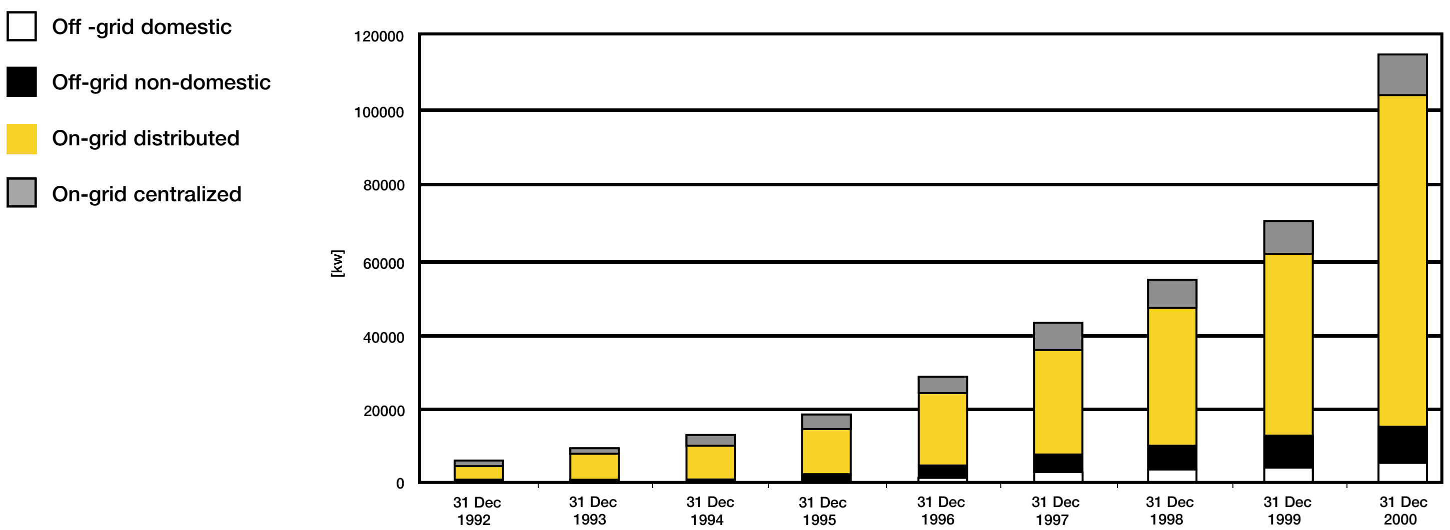
At the end of this programme the German PV market suffered a significant breakdown, however, and Greenpeace and other organisations started extensive lobbying work to encourage a follow-up. Greenpeace launched a solar pioneer programme in 1995 and has continued since then with extensive information work 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 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.

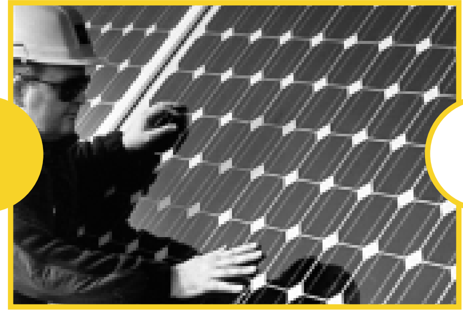
Germany

- PV CAPACITY END 2000: 114 MWp
- SUPPORT SYSTEM: 100.000 ROOFS PROGRAMME AND PREMIUM PRICE PER KWH

Figure 3.1: Installed PV in Germany by sub-market

Source:IEA





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 (currently 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 has accelerated the market dramatically. Under the REL, anyone who installs a solar generation system receives a buy-back rate of €0.5 per kWh over the system's lifetime. This payment will reduce by 5% each year from 2001 onwards, 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.

The government has since introduced stricter criteria for funding, with an upper limit of €6,579 on loans and no interest-free credit. For installations with an output above 5 kW loans are available on only 50% of costs.

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 €37m in 2000, 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. Even without a national target for PV, the programme could well see up to 438 MWp installed in Germany by the year 2004. Unfortunately it is not clear if the photovoltaic support scheme will be continued after 2004.

THE REST OF EUROPE

- **Spain** has an overall target to double its proportion of renewable energy to 12% by 2010. Solar power is supported by a guaranteed price of €0.4/kWh for systems under 5 kWp and €0.2/kWh for larger schemes. Some regional governments provide subsidies of 30-35% of installation costs. The present installed capacity of 10 MW should expand quickly, with prestige projects like a 40 kW system on the presidential palace leading the way.
- **Italy** is launching a Rooftop Program with the aim of stimulating the market through the installation of an initial 50 MW of PV roofs. Support for PV comes from a tax benefit on building refurbishment and a premium price of €0.22/kWh.
- **The Netherlands** has a target for 250 MWp by 2010 and 1,500 MWp by 2020. Various support programmes are available, including a new investment subsidy for households and housing associations. The world's largest PV housing project, "City of the Sun", will incorporate 5 MWp by 2004.
- Other European countries are also pursuing solar programmes, mainly targeted at the grid-connected sector. The UK, for instance, is considering a 70,000 roofs programme.

United States of America

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 (DoE) see this trend continuing or accelerating in the future as PV becomes more established as a preferred technology in key markets. The manufacturing industry's goal is to sustain a 20 to 25% annual growth over the next 20 years.

In terms of installations, PV has reached a level of 139 MWp, with 21.5 MWp being installed during 2000. Nevertheless, PV's overall contribution to electricity generation is still small – 267 million kWh compared to wind turbines at 3,585 million kWh.

Million Solar Roofs

An important boost to the PV market came in 1997 when President Clinton announced the "Million Solar Roofs Initiative" aimed at reducing the country's reliance on fossil fuels. Led by the DoE, the initiative looked to install solar panels on a million roofs by 2010. Thirty nine power utilities across the country announced plans for 900,000 solar systems on private buildings and 20,000 on federal buildings. Financial support would come from existing federal grants and other programmes and by working with local communities, businesses, state governments and utilities to spur solar sales.

Although the programme has been criticised for lack of direction, official figures show that 100,000 solar roofs had been installed by late 2000, almost double the expected goal of 51,000. One of the newest developments is a 100 kW PV installation dedicated in the state of Maryland in October 2000 – the largest thin film system so far constructed in the United States.

There is also a substantial US market for off-grid PV in remote houses, boats, motor homes and trailers. In the run-up to the end of 2000 millennium changeover, "Y2K" concerns and the Californian energy crisis of 2000- 2001 created a new interest in grid connected PV and led to a surge of sales of PV as a back up power system.

Policy

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 for PV have been considered by the US Congress. The 2001 National Energy Security Policy Act, for instance, would offer 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 the gradual **deregulation** of the US electricity industry. This enables individual states to open up trade in electricity generation, distribution and services. This has resulted in a number of initiatives beneficial to solar power, including **green pricing** schemes where consumers agree to pay extra for a supply of renewable electricity, a **renewables portfolio standard** 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. More than 35 states have also 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.

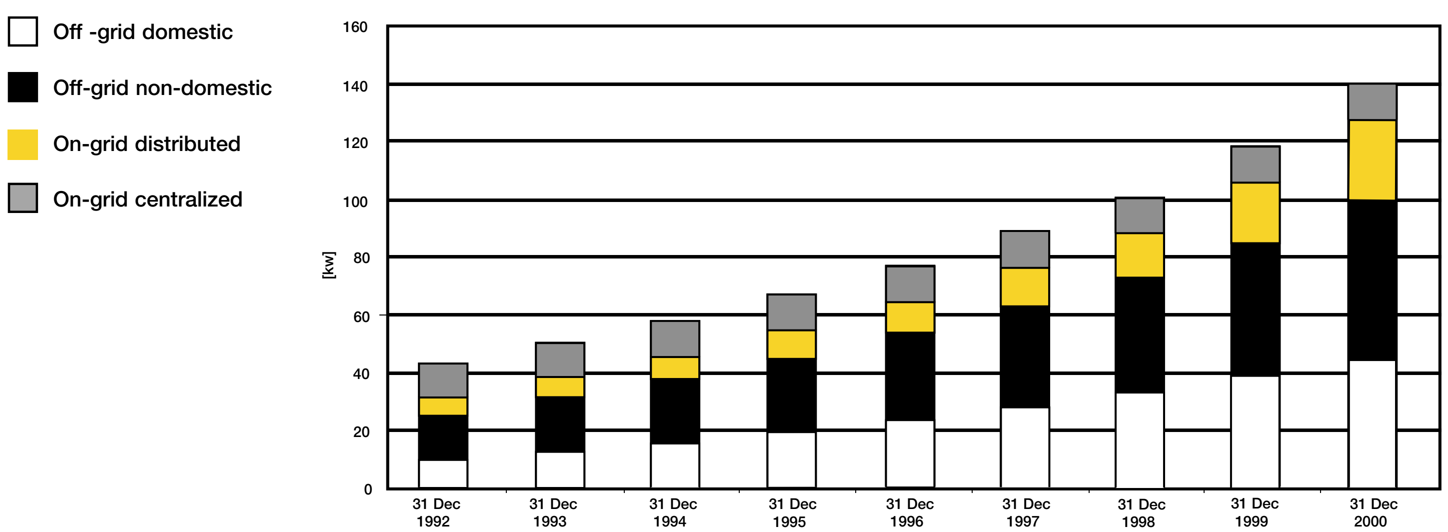
United States of America

PV CAPACITY END 2000: 146 MWp

SUPPORT SYSTEM: FEDERAL TAX CREDIT PLUS SEPARATE STATE INCENTIVES: MILLION SOLAR ROOFS INITIATIVE.

Figure 3.2: Installed PV in the US by sub-market

Source: IEA



Research and Development Programmes

Federal government spending on its National PV Program was $60.5m in 2000.

A major concern of DoE support programmes has been to reduce the cost of PV module production. The current goals are to achieve a $2/Wp solar module, with an annual production level of 250 MW, by 2002 and a $1/Wp module, with an annual production level of 1 GW, by 2004.

PV programmes initiated by DoE over the last decade include:

1. SOLAR 2000 (from 1991) aimed to develop partnerships with key stakeholders in the solar electric field, including the PV industry, utilities, regulators, international organisations and federal and state agencies. The utility component, called Photovoltaics for Utilities (PV4U) initiative, was designed to improve communications with state regulators and other state organisations.

2. The National Photovoltaic Programme (PVUSA) was aimed at enabling PV technology to become a significant part of the national energy mix by reducing the price of delivered electricity to 5-6 cents/kWh, raising system lifetimes to 30 years and increasing module efficiencies to 15%.

3. The PV Manufacturing Technology programme has included research into both amorphous silicon and thin film polycrystalline technologies.

4. The Solar Electric Industries Association (formerly the Utility Photovoltaics Group) aims to "expedite and facilitate the deployment of cost-effective and emerging high value applications of photovoltaics for the benefit of electricity utilities and their customers". This includes action at state level to encourage commercialisation of the technology by partnerships between utilities, the PV industry, customers and government, particularly through the Million Solar Roofs Initiative.
5. PV BONUS promotes opportunities for PV in the buildings sector, which represents about two thirds of the electricity consumed in the US.

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 until 2020. All non-hydro renewables, including geothermal, biomass and wind, could be providing 8 % of the country's electricity over the same timescale.

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 worldwide annual growth rate of 25% up to 2020, and with the goal of maintaining 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 worldwide, with 15 GW being 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 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.

STATE SOLAR INITIATIVES

- **The city of Chicago and 47 local government bodies have teamed together to purchase solar energy.**
- **New York State has selected three manufacturers of PV equipment to receive grants aimed at boosting the market for solar power. The NY legislature passed a law in 1997 which gives purchasers of PV arrays an income tax credit of up to $3,750 and guaranteed connection to the grid.**
- **The Los Angeles Department of Water & Power has launched a four year $38 m programme to provide clean solar power to its customers. A $6 m contract will go to AstroPower to supply the PV power modules. The programme will provide $5 per watt to qualifying customers who purchase and install their own PV systems. On average the incentives cover 50% of the cost. The LADWP aims to have 100,000 solar roofs installed by 2010. The rebate of $5/W is available to customers who source their system from LA, saving up to 60% of the cost. Siemens has already started building a manufacturing plant on the back of the scheme. Cosmetics firm Neutrogena will install a 200 kW system on its headquarters buildings at a cost of $1.4m.**
- **Sacramento Municipality Utility District in California has been running a PV support programme since 1993, most recently by offering systems at less than $3.50/W. In 2000, 1.6 MW was installed, mainly on commercial and official buildings.**

Japan

Renewable energy is seen as an indispensable part of Japanese climate change policy and carbon reduction targets, and 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 enthusiastic support 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.

Nearly all of the recent expansion in the Japanese PV market has been stimulated by the "70,000 Roofs Programme". This included an initial 50 % cash subsidy for grid-connected residential systems of 3-4 kW.

The programme is aimed at rapid expansion in the number of units coupled with a decreasing percentage of subsidy. During 2000 alone 108 MW of systems were installed, even though the subsidy had by then reduced to 35%. The overall goal is to stimulate production, bring prices down, create market awareness and leave Japanese industry with a fully economic market which would encourage competitive exports to the rest of the world.

The solar roofs programme has been supported by substantial funding from the Japanese government. In Fiscal Year 2001, a total of $198m was provided in finance to residential solar generating systems. This was expected to take the total number of installations supported up to 53,000, with a capacity of about 200 MWp.
A capital subsidy of 67% is also available for PV installations on commercial buildings. One result is that the world's largest PV solar site is now operating in Tokyo at the head office of telecommunications giant NTT. The company also plans to install PV panels on 10 % of public phone booths.

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, especially through "Project Sunshine". Japanese PV budgets grew from $20 million in 1980 to over $150 million in 1997.

During FY 2001 the budget for PV support provided by the Ministry of Economy, Trade and Industry (METI, formerly MITI) rose only slightly to $271m. Compared to other OECD countries, however, this is a major commitment. Among the areas of new or increased funding are technological improvements to PV power generation, aid for entrepreneurs setting up PV businesses and support to NGOs (non-governmental organisations) and municipalities.
Some of Japan's national PV programmes include:

- 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 **Residential PV System Dissemination Programme** aims to promote PV by subsidising the installation cost for individuals and housing suppliers on condition that they "appreciate its significance" and provide operational data from their system. This supports the "70,000 Roofs Programme" and has made PV a standard part of the specification for new housing.
- **PV Field Tests** collect data on the operation and installation costs for both industrial and public building systems. More than 150 systems on industrial buildings and over 1,800 on public buildings have been supported by this programme.
- **PV on Public Buildings:** A total of 23 MW has been installed on schools and government buildings under this programme.
- Many of the main government ministries have their own programmes to promote PV use.

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 75%. In the near 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 some three times higher than 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 recent introduction of premium green pricing for renewable electricity.

All ten Japanese regional power utilities introduced a "Green Power Fund" at a monthly rate of $4 from October 2000, with the companies matching this amount towards the installation of new renewable plant.

Future prospects

At the end of FY 2002 METI intends to halt government subsidies for domestic solar power generation in order to boost competition in the industry. The argument for this is that before subsidies were introduced, the estimated cost of generating 1 kW of electricity using solar was $32,700. This figure has already dropped to $6,500, and solar could compete with other grid-connected electricity if the price dropped further to about $3,270. It is therefore anticipated that manufacturers should be able to achieve the additional cost reduction by the time the subsidies end.

An analysis of the economics of Japan's PV residential programme has shown, however, that with a 30 % subsidy and a relatively high $0.22/kWh electricity price, many Japanese are still willing to pay a premium for PV supply. The concern is that when the support programme comes to an end the cost of unsubsidised PV will prove too expensive for them. Many observers believe that the Japanese government will introduce a new support system when the present one expires.

National targets

Following the climate change summit at Kyoto in 1997, Japan announced an accelerated target to install 5,000 MW of PV by 2010. The total potential for PV power generation in Japan is as much as 173 GW, according to calculations made last year by METI, although a realistic level would be in the range 42-86 GW.

Prime Power

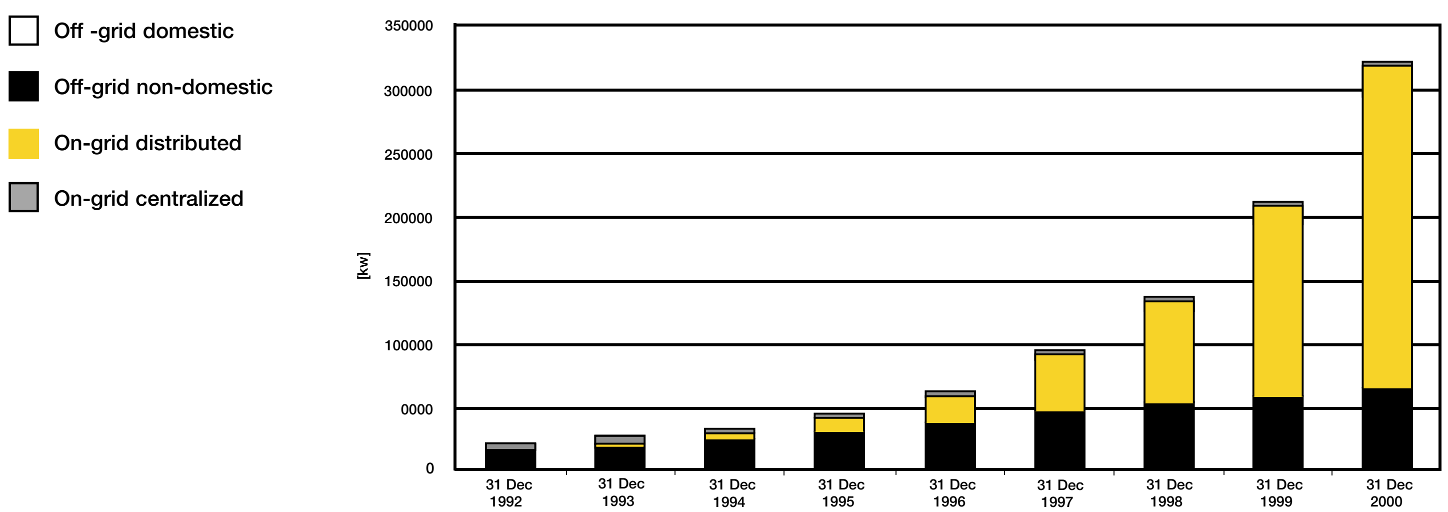
PV has been installed on a new building at the official residence of the Japanese Prime Minister, a symbol that solar power is central to the country's future energy regime.

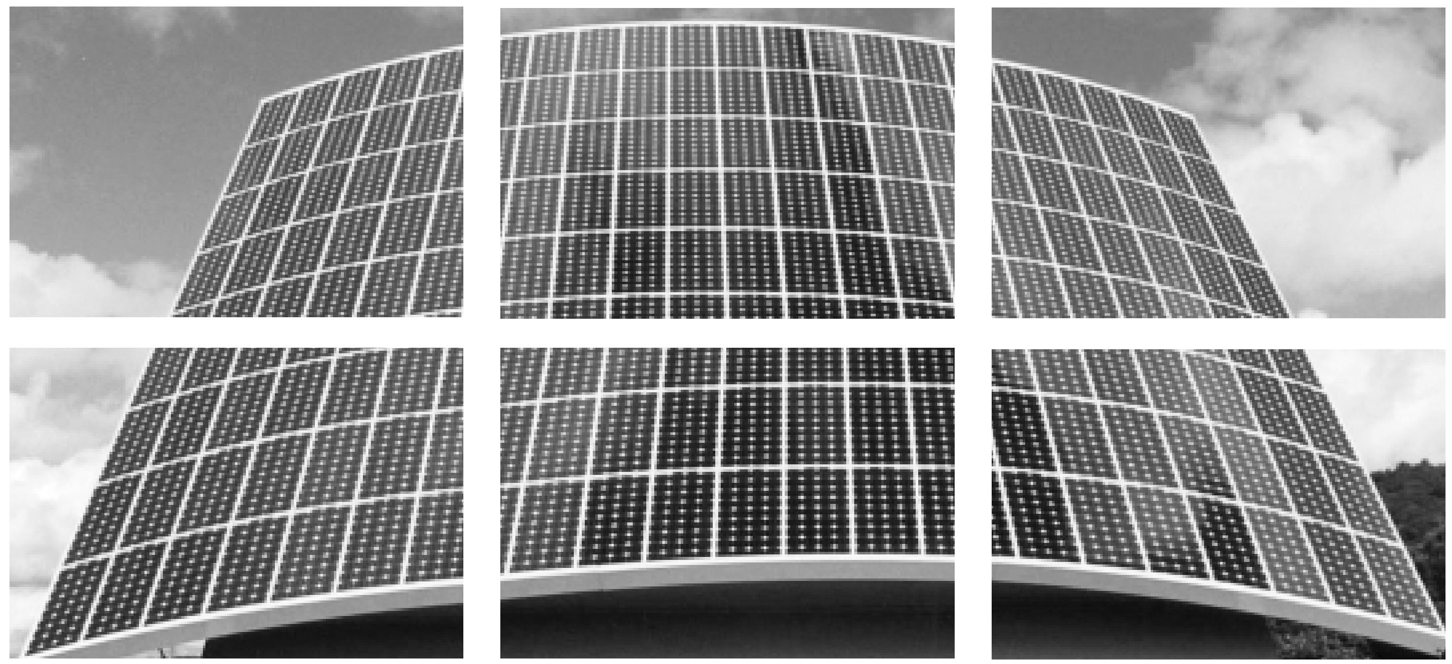
Japan

- PV CAPACITY END 2000: 314 MWP
- SUPPORT SYSTEM: VARIOUS GOVERNMENT SUPPORT PROGRAMMES, INCLUDING UP TO 50% GRANT FOR DOMESTIC PV ROOFS.

Figure 3.3: Installed PV in Japan by sub-market

Source: IEA





PART FOUR:
THE SOLAR FUTURE

Methodology and assumptions
The EPIA/Greenpeace Scenario

If solar electricity 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 twentieth 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 and a range of factors, including global development aid, kicks in. The average annual growth rate worldwide up to 2009 is projected to be 27% and then rising to 34% between 2010 and 2020. Although initial growth is expected to be fastest in the grid-connected sector, by 2010 this will be replaced by the emerging off-grid rural sector.

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 27,350 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. 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 20 years has been assumed for PV modules. As a result, the capacity installed during 2001 has been subtracted from the figure for cumulative installed capacity reached by 2021. This methodology has then been applied to all the subsequent years between 2022 and 2040.

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.

Key results
Solar Generation – PV in 2020

These are the headline findings of the EPIA/Greenpeace "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.

1. Power Generation
The EPIA/Greenpeace scenario shows that by the year 2020, PV systems could be generating approximately 276 Terawatt hours 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 30% of the entire continent of Africa, or 10 % of the European Community.

Global Solar Power in 2020 Solar Electricity Production

	276 TWh Projection to 2040	1% of total global demand 30% of total demand in Africa 10% of total demand in Europe 9,113 TWh 26% of global demand
PV Systems Capacity		207 GWp
Grid-Connected Consumers		82 million worldwide 35 million in Europe
Off-grid Consumers		1 billion worldwide
Employment Potential		2,3 million full time jobs
Investment Value		$75 billion per annum
Cost of Solar Modules		Less than $1 per Wp
Carbon Savings		664 million tonnes of carbon dioxide (cumulative total)

Global installed capacity of solar power systems would reach 207 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, each serving partly the needs of three people, the total number of people by then generating solar electricity with a grid connected solar system would reach 82 million. In Europe alone there would be roughly 35 million people generating solar electricity with a grid connected solar system.

In the non-industrialised world approximately 30 GWp of solar capacity is expected to have been installed by 2020. Here the assumption is that ten out of the 30 GWp will be used for housing, with an average system size of 50 Wp and five people per dwelling. Since systems sizes are much smaller and the population density greater, this means that up to a billion people in the developing countries would by then be using solar electricity. This would represent a major breakthrough for the technology from its present emerging status.

By 2040, the penetration of solar generation would be even deeper. Assuming that overall global power consumption had by then increased from 27,000 to 35,000 TWh, the solar contribution would equal 26% 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 between 2000 and 2010 20 jobs are created per MW of capacity during manufacture, decreasing to 10 Jobs per MW between 2010 and 2020. and about 30 jobs per MW during the process of installation, retailing and providing other local services between 2000 and 2010, going down 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 1 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 2.3 million full time jobs would have been created by the development of solar power around the world.** Over half of those would be in the installation and marketing of systems.

30 JOBS PER MW IN THE RETAIL CHAIN, THE INSTALLATION PROCESS & OTHER SERVICES

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 a new cell production site 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 of a 20% progress ratio, **the cost of "ready to install" modules would fall by more than two-thirds – from $3.00/Wp now to less than $1.00/Wp in 2020.**

In terms of delivered electricity, it is possible to make predictions for the output from grid-connected systems. The results are given for an average consumer in some of the major cities of the world *(see table 4.1)*. These show that by 2020 the cost of solar electricity in the most insolated regions – the Middle East, Asia , South America and Australasia – will have more than halved to as little as 10-13 US 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 shows that a total of almost $57 billion will need to be invested in new production facilities between 2000 and 2020. By the end of the period the annual investment will have reached a level of over $14 billion
The global value of the solar power market will have reached more than $69 billion by the end of the scenario period. Investment in new production facilities will reach $14 billion by 2020. The overall market volume for modules will increase to $46 billion. Just over $11 billion of the total solar electricity marked will be located in Europe, $9.5 billion in the Pacific region and $5.2 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.

As the world's solar electricity production increases, there will be equivalent reductions in the amount of carbon dioxide emitted 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. With increased efficiency in production this will decrease to less than one year.
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 164 million tonnes. This reduction is equivalent to the emissions from all 44 million cars currently operating in Germany or 75 coal-fired power plants. Cumulative carbon dioxide savings from solar electricity generation between 2000 and 2020 will have reached a level of more than 727 million tonnes, equivalent to two-thirds of Germany's total CO_2 emissions in 2000.

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 UScents/kWh *(see box page 29)*. These external costs must be taken into account when comparing solar systems with other energy sources.

Figure 4.1: Growth in world solar market by application

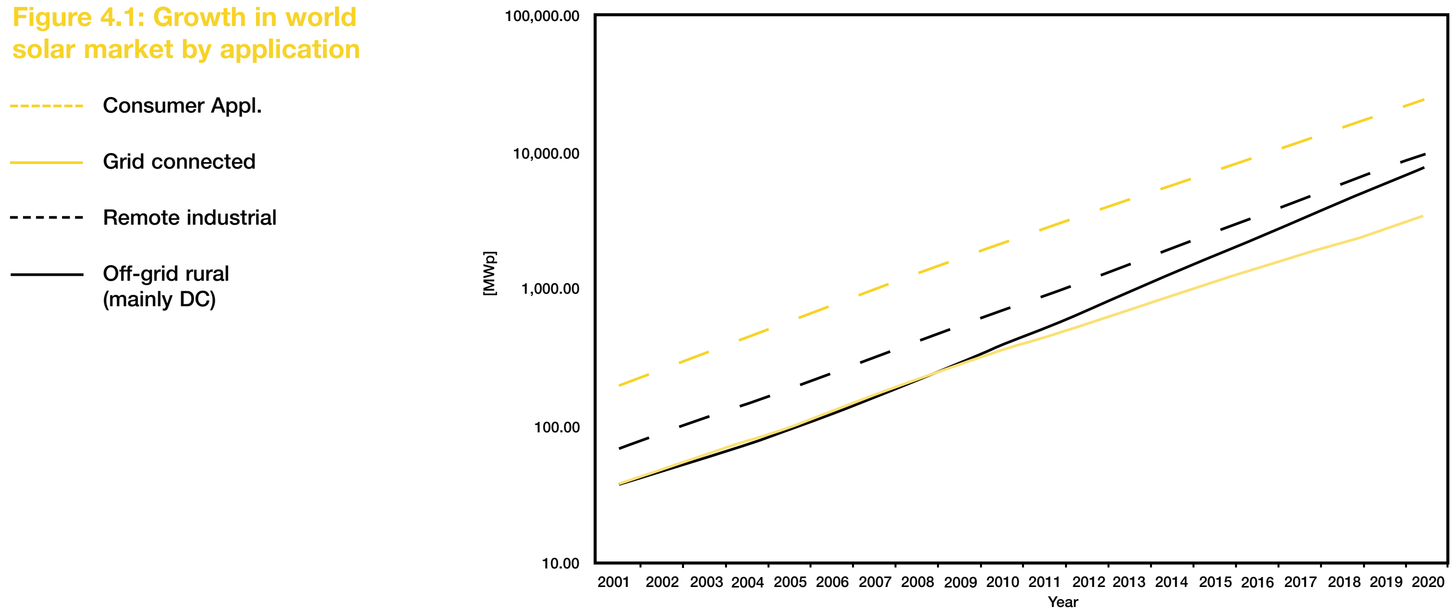


Figure 4.2: Global solar electricity generation - 2000-2020

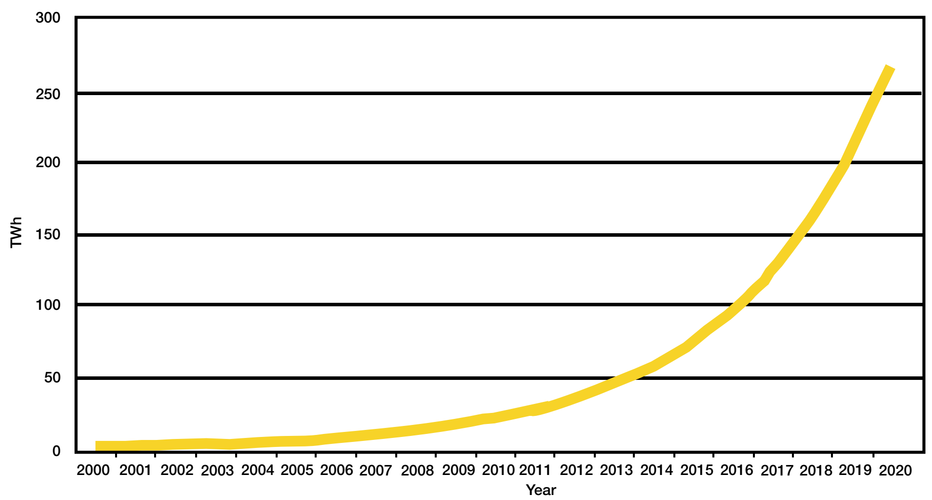


Figure 4.3: Employment in PV related jobs worldwide

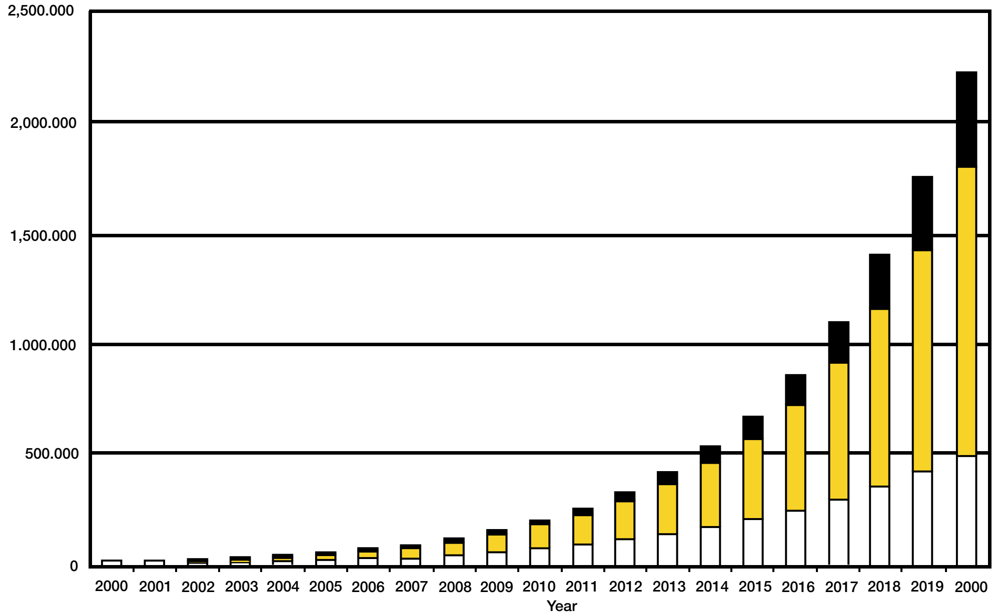


Figure 4.4: Module cost reduction in US$/Wp

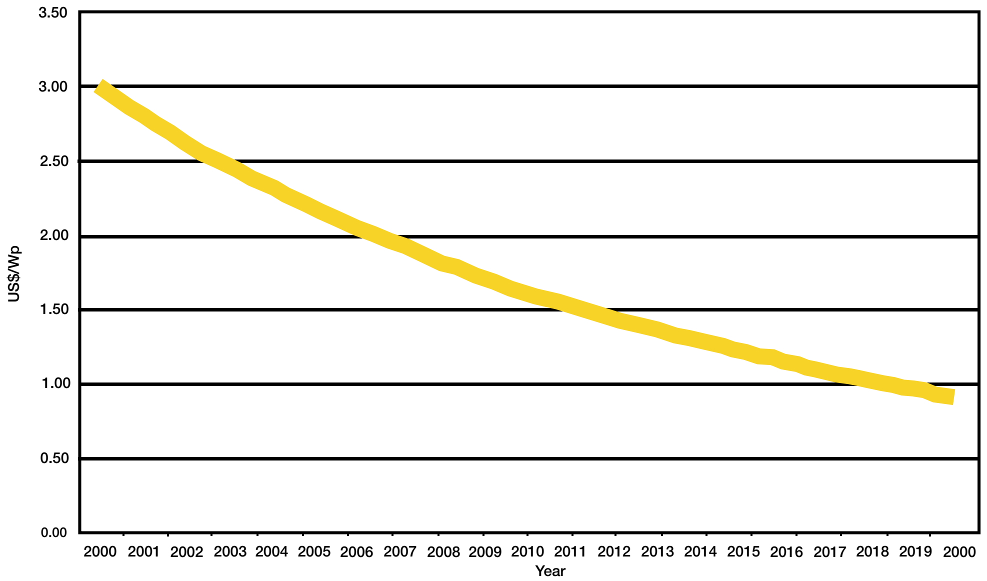


Table 4.1: Fall in price of PV electricity in selected cities 2000-2020

Cities	kWh/year	2000 $/kWh	2005 $/kWh	2010 $/kWh	2015 $/kWh	2020 $/kWh
Berlin	900	0.45	0.41	0.30	0.27	0.20
Paris	1000	0.40	0.37	0.27	0.24	0.18
Washington	1200	0.34	0.30	0.23	0.20	0.15
Hongkong	1300	0.31	0.28	0.21	0.18	0.14
Sydney / Buenos Aires	1400	0.29	0.26	0.20	0.17	0.13
Bombay	1400	0.29	0.26	0.20	0.17	0.13
Bangkok	1600	0.25	0.23	0.17	0.15	0.11
Los Angeles	1800	0.22	0.20	0.13	0.13	0.10

Figure 4.5: Global investment in new PV production facilities

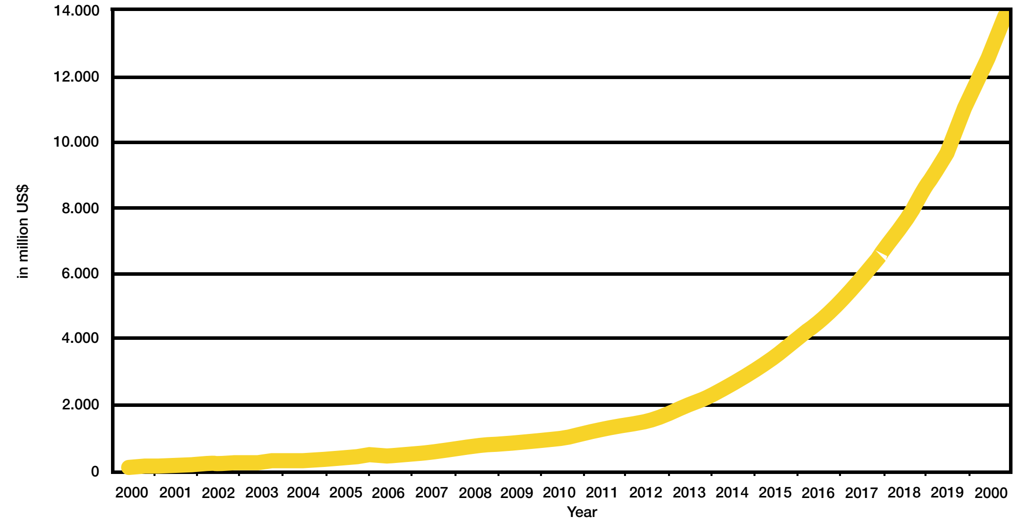


Figure 4.6: Value of regional PV markets in $m 2000-2020

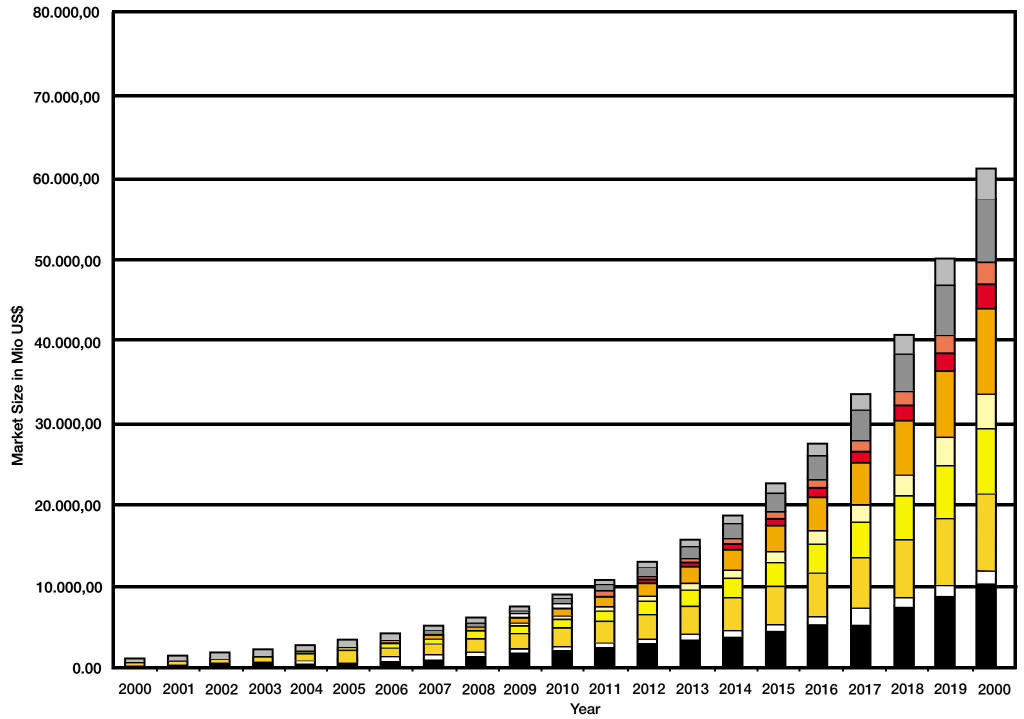
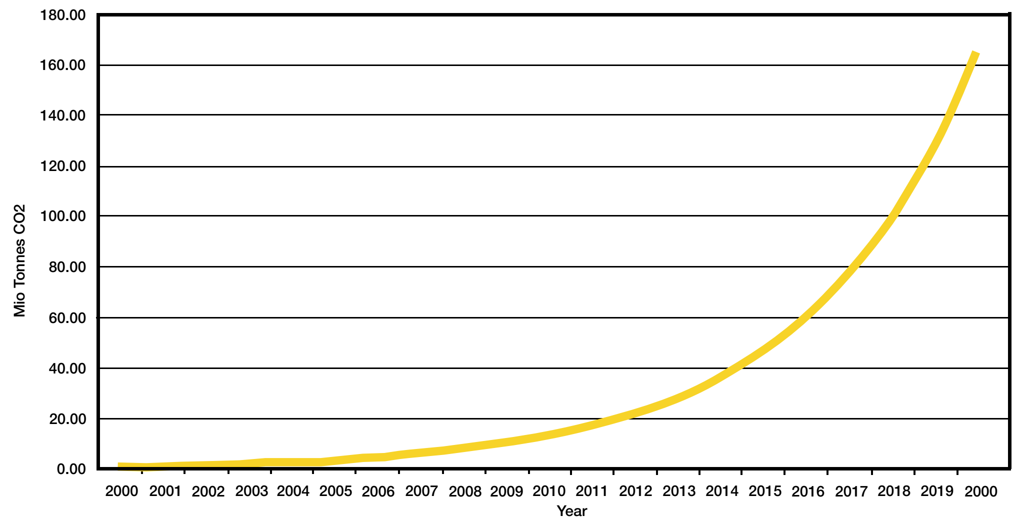


Figure 4.7: Annual global CO_2 savings in millions of tonnes



EXTERNAL COSTS OF ELECTRICITY GENERATION

The external costs to society derived from burning fossil fuels or from nuclear generation are not included in most electricity prices. These costs have both a local and a global component, the latter mainly related to the eventual consequences of climate change. There is an 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$/tonnes CO_2
- Medium 20.7 – 52.9$/tonnes CO_2
- High: 160$/tonnes 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$/ton CO_2.

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.

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 in the 15 EU states by the year 2010. This scenario demonstrates that this goal is realistic to be achieved by 2010.
Reasons for this optimism include the fact that the PV market in Germany grew by 184% between 1999 and 2000. 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 price payments for renewable energy output. Further strengthening of this mechanism came with the introduction of the Renewable Energy Law in April 2000.
It is anticipated that other European countries will develop similar programmes. There are already plans for further development of the PV market in Spain, Italy and Luxembourg. Other countries, such as the UK and Austria, are discussing the introduction of incentives.

Case Study: Solar Generation in Germany

Germany is currently the key player in the European PV market (see Part Three: The Solar Race). As a result of the support provided by the Renewable Energy Law, together with the 100,000 roofs programme, the annual growth rate between 2000 and 2005 is expected to be 30%. The roofs programme is scheduled to end in 2003, however. The annual growth rate is therefore assumed to drop to 27% between 2006 and 2009 and to 20% between 2010 and 2020.

The table below 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 2.0 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% of Germany's electricity demand and by 2020 more than 3%.The cumulative installed capacity in Germany in 2020 would be 15.300 MW.

Within the next 20 years the German PV industry could create 83,000 jobs in the retail chain, installation, maintenance and other services. If all the modules were manufactured in Germany itself this would create up to 50,000 additional jobs.

Government policy and programmes

If this scenario is to be realised then the "feed-in tariffs" available under the extremely effective Renewable Energy Law will have to be expanded from 2004 onwards in order to avoid a collapse of the solar PV market. If the 100,000 rooftop programme is not extended, the feed-in-rate should be increased in order to cover capital costs during the first few years. The tariff could later decrease annually in relation to the progress ratio on the production side. This phase-in programme should lead to a self-sufficient market and much lower costs for PV installations. Export programmes are also needed to maintain the market

Annual solar electricity market (MWp) by region

Year	OECD Europe	OECD-N America	OECD-Pacific	Latin America	East Asia	South Asia	China	Middle East	Africa	Rest of world	Total (MW)
2000	58,00	23,30	114,00	15,00	4,00	20,00	4,00	3,00	10,00	2,00	**253,30**
2005	207,19	57,98	376,64	55,69	17,94	66,08	12,21	9,16	30,52	4,98	**838,37**
2010	740,16	150,28	1.104,16	230,65	86,38	273,65	50,55	37,92	126,38	20,61	**2.820,74,**
2015	2.644,07	458,61	3.236,98	1.478,39	553,70	1.754,00	324,03	243,03	810,09	132,10	**11.635,01**
2020	9.445,44	1.399,58	9.489,62	9.478,10	3.549,05	11.242,68	2076,98	1.557,73	5.192,44	846,75	**54.276,37**
Total 2000-2020	**41.075,76**	**6.851,34**	**47.328,94**	**30.430,18**	**11.375,84**	**36.112,87**	**6.672,80**	**5.004,60**	**16.682,00**	**2.721,91**	**207.076,99**

Solar generation in Germany: Annual market numbers

Year	MW	MWh	tCO2	Market Volume in Mio. US$	Jobs -30 Jobs per MW for installation plus 1 Job per operating MW
2000	44,30	44.300	26.580	173	1.329
2005	149,26	530.951	318.570	454	4.595
2010	437,30	2.043.996	1.226.398	991	13.483
2015	1088,13	5.949.019	3.569.411	1.803	33.551
2020	2707,62	15.665.964	9.399.578	3.205	83.485
Total 2000 till 2020	**15665,96**	**83.946.196**	**50.420.810**		

development 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.(called C.L.E.) 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 5 GWp installed PV capacity by the year 2010. From 1999 to 2000 the market grew by 51.6%, 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 growing domestic demand to an expanding industrial sector. 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. Having lost its position as the country with the largest per capita PV use, it now has the opportunity to rebuild. Promising signs are that BP Solar recently opened a 25 MW factory in Sydney and Pacific Solar plans a 20 MW thin film factory in 2005.

The current market is dominated by off-grid applications (80% of the total), and the grid-connected sector, still very small, received its most important boost from the installations at the 2000 "Green Olympics" in Sydney. Nearly half of the PV capacity in New South Wales is at the Olympic Park, solar units were used to provide power to 665 houses in the athletes' village as well as a number of other buildings. But although there has been some activity in building-integrated systems following the Olympics, including a planned further 480 houses, little has been done to capitalise on one of the world's best known solar success stories.
Existing government support programmes have largely been taken up by systems in remote areas, which achieve little transformation of the solar PV market. With 92% of Australians living in urban areas, the greatest potential exists in cities.

Government policy and programmes

Last year's new installations were dominated by systems built using the Australian government's PV Rebate Program. This has provided up to 50% of capital costs for building integrated systems, although half of the AU$31 million allocated to the programme was used in the first year. The criteria have now been tightened and applications are slowing, but it is very doubtful that this programme will lead to the creation of a mature BIPV market. The solar industry needs long-term and well targeted support based around a plan for market developed and sustained growth. Nothing will be achieved by short-term "boom and bust" subsidy schemes.

A new programme aimed specifically at the off-grid market begins in 2001, funded by a tax on diesel fuel. This has a budget allocation of roughly AU$ 200 million over four years, available for all renewables. With a well established network of suppliers, and clear benefits, this programme has the potential to see reasonable increases in PV use as a replacement for diesel in remote areas, but does nothing to tackle the use of grid-connected solar in the country's most populated regions.



Figure 4.8: World Solar Power Market by Region 2000

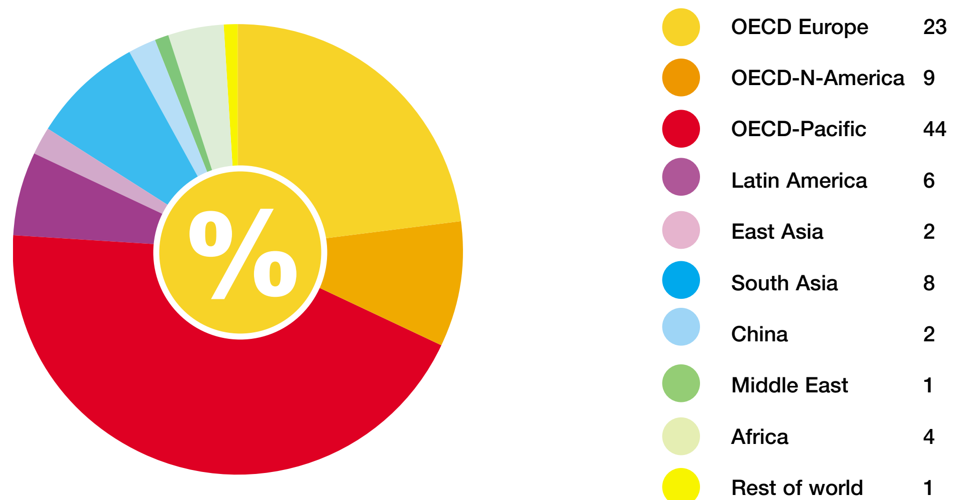


Figure 4.9: World Solar Power Market by Region 2010

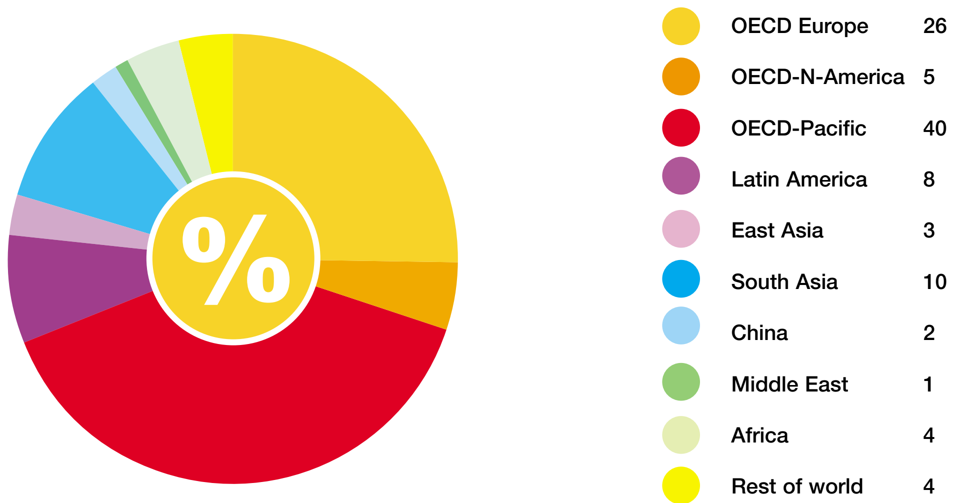
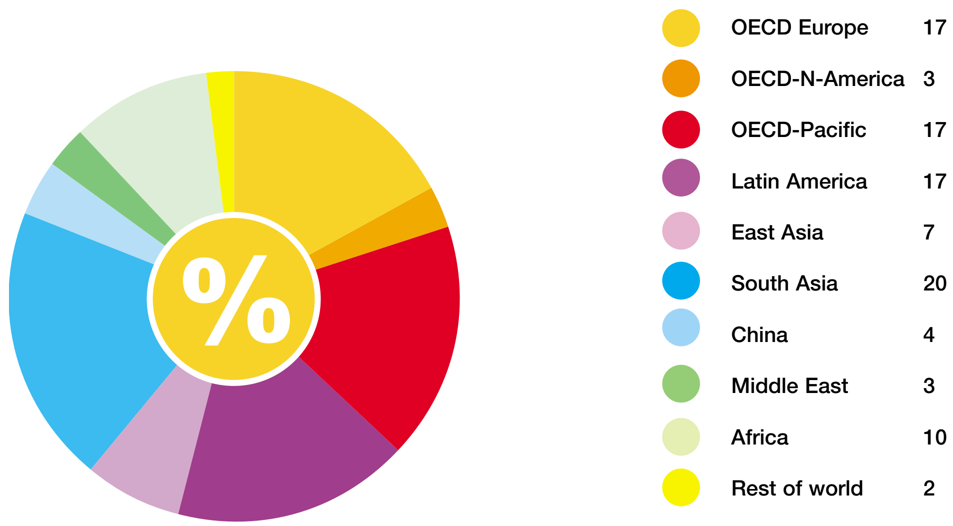


Figure 4.10: World Solar Power Market by Region 2020



For grid-connected systems, guidelines developed by power utilities and the PV industry under the auspices of the Electricity Supply Association of Australia are in the process of becoming an accepted standard. This should encourage further support from the government.

Several government programmes aimed at commercialisation of renewable energy technologies have also benefited PV. Over AU$ 7.5 million in grants was provided in 2000 to a variety of PV production facilities, products and demonstration systems. A further AU$ 1.1 million was provided for battery and charge controller development.

With overall electricity demand forecast to increase by 36% over the next decade, a new mandatory renewable energy target for an additional 9,500 GWh by 2010 was introduced by the Australian government in 2001. This will apply to electricity retailers and large users. However, the lack of technology banding, a least cost approach and weak penalty clauses mean that the current law will do little to create a sizeable PV market. Based on experience in the solar heating market, if the mandatory target was increased and the price of solar PV reduced, it is possible that a similar market stimulation could result for the PV industry, although electricity retailers would need to be more receptive to distributed generation.

In the EPIA/Greenpeace scenario, concerted action by industry and the government would lead to a strong solar PV industry in Australia, with a ten-fold increase in production capacity to approximately 250 MW by 2010. By 2020 the market volume would reach 2,500 MW. The relatively small number of jobs created could be much higher if the manufacturing industry also focused on exports.

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 MW and a growth in 2000 of just 1.3 MW.

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 the future prospects.

Case Study: Solar Generation in the United States

Because of the current key position of the US in the solar PV market, two different scenarios have been calculated. The first scenario is “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 and Japanese competitors.

Figure 4.5 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 nation wide support scheme similar to those operating in Germany or Japan, then the a different market development would be possible *(see table 4.6)*. This “take-off” scenario assumes that the US domestic market will develop along the lines of Europe. To be one or two years ahead of the EU market, and therefore not fall behind in the solar race, a target of 1,500 MW cumulative capacity by 2005 is necessary. To achieve this, a strong market growth is required. After 2005 it is assumed that the annual growth rate is 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. The industry would create more than 700,000 jobs and, assuming that consumption increases by 40%, the share of national electricity output would be 4% in 2020.

Government policy and programmes

The conclusion of the scenario for US federal and state energy planners is that if the US 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.

BY 2020 AN ESTIMATED 2.3 MILLION FULL TIME JOBS WOULD HAVE BEEN CREATED BY THE DEVELOPMENT OF SOLAR POWER AROUND THE WORLD.

Table 4.3: Cumulative installed PV in Australia by sub-market

Source: IEA

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
off-grid domestic	1560	2030	2600	3270	4080	4860	5960	6820	9110
off-grid non-domestic	5760	6865	8080	9380	11520	13320	15080	16360	17060
on-grid distributed		5	20	30	80	200	850	1490	2390
on-grid centralised				20	20	320	630	650	650
Total	**7300**	**8900**	**10700**	**12700**	**15700**	**18700**	**22520**	**25320**	**29210**

Table 4.4: Annual solar market in Australia to 2020

Year	MW	MWh	tCO2	Market Volumes in Mio.US$	Jobs -30 Jobs per MW for installation plus 1 Job per operating MW
2000	3,89	5.446	3.268	18	**117**
2005	73,50	224.731	365.535	164	**1.688**
2010	263,47	1.724.086	852.762	659	**8.114**
2015	820,25	5.257.622	3.154.573	1.510	**25.261**
2020	2553,68	17.201.275	10.320.765	3.471	**78.645**
Total 2000 till 2020	**12286,63**	**78.314.913**	**46.988.948**		

Table 4.5: Annual solar market in US to 2020 (business as ususal)

Year	MW	MWh	tCO2	Market Volumes in Mio.US$	Jobs
2000	22	41.940	72	86	**660**
2005	55,74	658.810	365.535	164	**1.688**
2010	136,22	1.724.086	893.494	299	**4.200**
2015	338,95	4.414.975	2.207.225	551	**10.451**
2020	843,43	11.110.76	5.476.2081.	017	**26.006**

Table 4.6: Solar market in the US to 2020 (take-off scenario)

	MW	MWh	tCO2	Market Volumes in Mio.US$	Jobs -30 Jobs per MW for installation plus 1 Job per operating MW
2000	22,00	39.600	72	86	660
2005	704.00	2.710.800	1.626.480	2.100	21.472
2010	2513.37	17.427.079	10.456.247	5.448	77.412
2015	7670,19	63.838.481	38.303.088	12.237	236.242
2020	23407,56	205.474.839	123.284.903	27.573	720.953
Total 2000 till 2020	**106984,35**	**905.733.546**	**543.440.128**		

Table 4.7: Annual solar market in India to 2020

Year	MW	MWh	tCO2	Market Volumes in Mio.US$	Jobs -30 Jobs per MW for installation plus 1 Job per operating MW
2000	10,50	14.700	8.820	47	315
2005	38,99	187.514	112.508	134	1.200
2010	202,19	1.013.406	608.044	506	6.215
2015	906,61	4.817.297	2.890.378	1.669	27.870
2020	4065,27	21.874.071	13.124.442	5.525	124.969
Total 2000 till 2020	**15624,34**	**83.111.068**	**49.866.641**		

Table 4.8:Annual solar market in Thailand to 2020

Year	MW	MWh	tCO2	Market Volumes in Mio.US$	Jobs -30 Jobs per MW for installation plus 1 Job per operating MW
2000	1,00	1.300	780	5	30
2005	16,41	48.053	28.832	58	502
2010	58,60	295.845	177.507	153	1.805
2015	178,82	1.077.316	646.390	342	5.508
2020	545,72	3.462.178	2.077.307	745	16,808
Total 2000 till 2020	**2604,62**	**15.946.228**	**9.567.737**		

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 government's current Five Year Plan (1998-2002) envisages the installation of 70 MWp of solar PV, including 50,000 solar lanterns, 150,000 home systems and 5,000 solar pumps.

The EPIA/Greenpeace scenario is based on an average growth rate between 2000 and 2020 of 35%. The Indian PV market in 2020 would then be the biggest in the world. If all the systems installed were manufactured in India itself this would add a further 81,300 jobs to the 124.000 jobs expected to result from work on installation, retailing and other services.

Government policy and programmes

The Indian government needs to continue demonstrating its commitment tomainstream 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 technolgies.

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 2000. To build up a stable and self-supporting solar PV market by 2010 a support programme for solar PV is needed. The EPIA/Greenpeace scenario is based on a target for 40 MW installed capacity by 2005. Even with a moderate market growth rate of 30% between 2006 towards the end of the scenario period, the market in Thailand looks very promising.

With solid development over the succeeding years, however, Thailand could be one of the most important PV markets in the East Asia region. Within ten years, this would create more than 1,800 jobs in installation, retailing and other services. By 2020 more than 16,000 jobs could be expected in installation, retailing and other services, with additional potential in manufacture and development.

Government policy and programmes

The Thai government should demonstrate its commitment to PV by providing incentives to 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 electric supply, water pumping, cathodic protection and signposting. Rural

Table 4.9: Annual Solar market in Argentina to 2020

Year	MW	MWh	tCO2	Market Volumes in Mio.US$	Jobs -30 Jobs per MW for installation plus 1 Job per operating MW
2000	1,00	1.400	840	5	30
2005	32,00	88.200	52.920	112	976
2010	118,81	614.870	368.922	311	3.656
2015	441,15	2.570.360	1.542.216	843	13.574
2020	1637,95	9.830.955	5.898.573	2.237	50.398
Total 2000 till 2020	**6903,30**	**40.799.004**	**24.479.402**		

electrification programmes have been supported with funding from the World Bank and the Global Environment Fund. Despite activity in this area, however, there still remains a huge unserviced rural market.

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

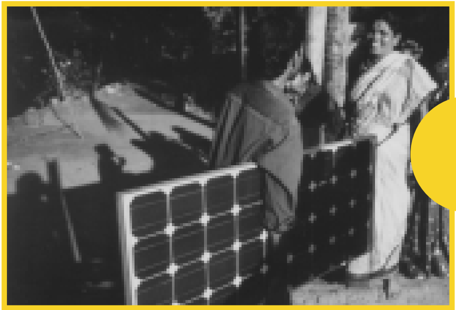
The Energy Department recently announced a new rural electrification program called PERMER (Renewable Energies Program for Rural Markets) funded by the World Bank and by new subsidies from the GEF. The aim is to invest a total of $120 million, with additional grants from the national and provincial governments, to reach some 1,800 off-grid rural homes with renewable before the year 2004. Should it come to fruition, this programme should strongly encourage solar power.

During 1999 Greenpeace launched a "Solar Solidarity" project to encourage the development of links between urban schools and rural schools without electricity. The city schools use educational activities to spread the solar message and raise funds for photovoltaic equipment to be installed in their rural counterparts.

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.

To build up a solid ongoing solar PV market in Argentina it is clear that a national support programme is needed. The EPIA/Greenpeace scenario is based on a target for 65 MW of installed capacity by 2005. From then on, even with a moderate growth rate of 30% between 2006 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 25% share of the Latin American market. Within ten years this would create more than 3,500 jobs in installation, retailing and other services. By 2020 more than 50,000 jobs could be expected in installation, retailing and other services, with additional potential in manufacture and development.






Government policy and programmes

A national Regime for Grid Connected Renewable systems including net metering and small cheap credits for home solar systems is needs. A goal for solar pv needed to be established:

5000 solar roofs for 2004. This could be financed by switching current subsidies for nuclear power to solar systems, to help owners to buy grid connected systems. A solar school programme is urgently needed to power 2000 rural schools without electricity by 2003.

Also the rural electrification programm neededs to be completed within the next 5 years.

And clean energy projects should be taken as a priority for CDM investments, excluding sinks projects.

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. 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 programmes, 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 has already installed a generation capacity of well over 10 MW.

In the EPIA/Greenpeace scenario China is expected to produce a growth rate of about 27.5% over the next decade. This will increase to 45% between 2010 and 2020.

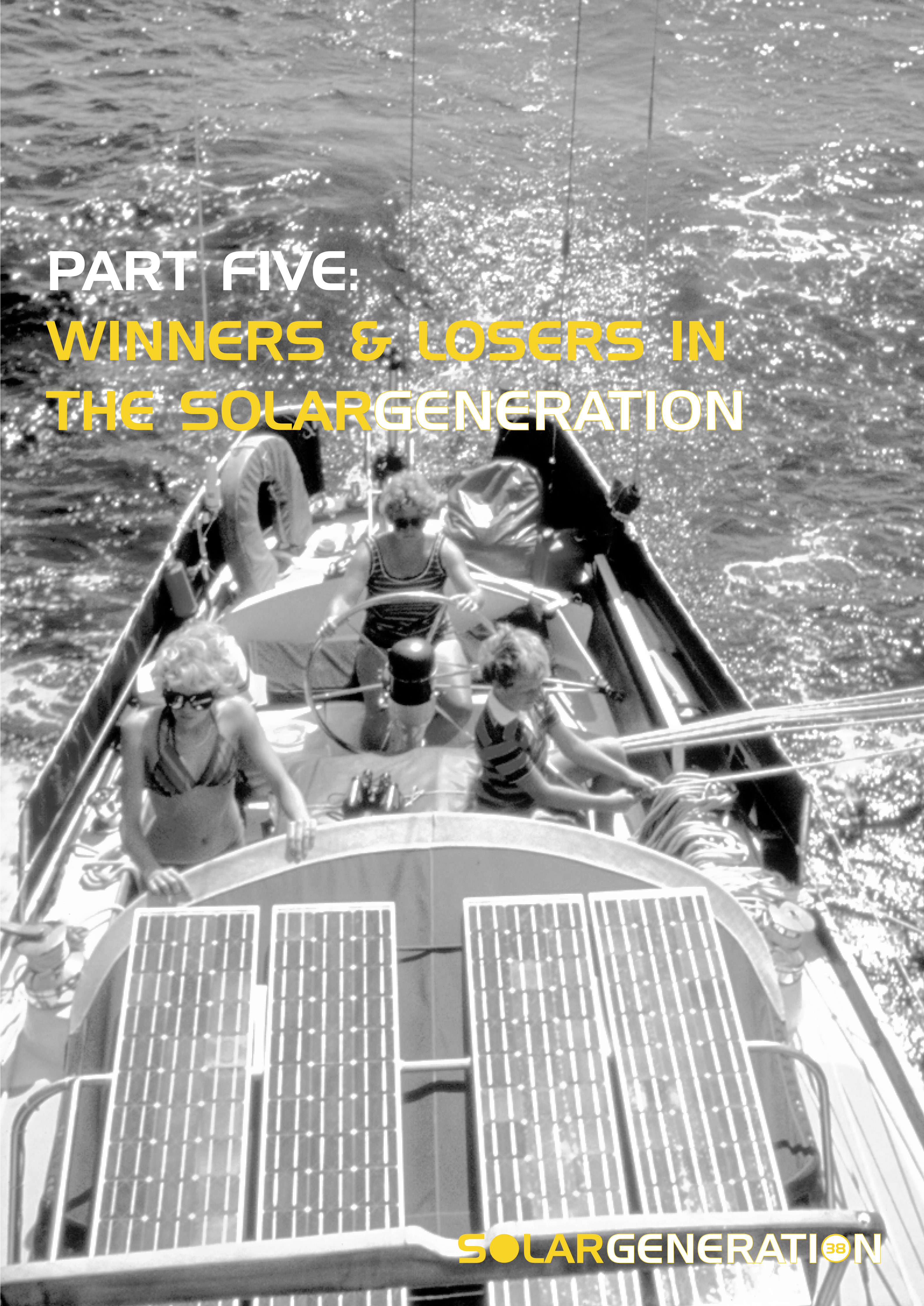
In 2020 the Chinese solar PV market could be the third largest in the world, creating nearly 65,000 jobs in in instillation, retailing and other services. The total energy output in 2020 would be 8.8 TWh, the equivalent of three coal-fired power plants. This market development needs a strong and long-term support programme for solar PV.

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.

Figure 4.10: Solar market in China to 2020

Year	MW	MWh	tCO2	Market Volumes in Mio.US$	Jobs -30 Jobs per MW for installation plus 1 Job per operating MW
2000	4,00	65.000	39.000	18,00	120
2005	12,21	123.546	74.127	42,82	376
2010	50,55	316.902	190.141	132,24	1.551
2015	324,03	1.462.484	877.491	619.47	9.945
2020	2076,98	8.805.361	5.283.217	2.837,03	63.742
Total 2000 till 2020	**6672,80**	**29.990.336**	**17.994.202**		



PART FIVE:
WINNERS & LOSERS IN THE SOLARGENERATION

The speed with which the solar electricity sector is increasing its market share, 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.

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.

Net metering and premium tariffs

On the support side, customers must also not be heavily 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 of supporting solar must meanwhile be promoted. At the very minimum these include net metering and the wide-scale introduction of premium tariffs for solar electricity. The latter have been exceptionally efficient at promoting the uptake of solar electricity in the German market.

New market opportunities

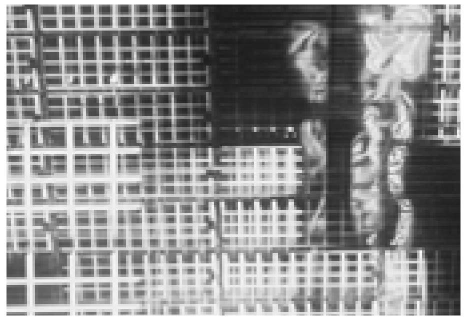
Clearly, just as with other emerging technology markets, decisions are not without their associated financial risks. The clear upward trend of current market developments, however, point to major opportunities for both existing and new players in the solar electricity sector. The expanding list of companies and consortia currently formulating strategies for exploiting the solar market, or developing business plans for entering it, are positioning themselves as the key players.

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.

INDUSTRIAL REVOLUTIONS GIVE RISE TO BOTH WINNERS AND LOSERS.



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, Japan and the Netherlands, 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, whilst the influential Economist magazine recently 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.