IEA INTERNATIONAL ENERGY AGENCY

TRENDS IN PHOTOVOLTAIC APPLICATIONS

in selected IEA countries between 1992 and 2000

PVPS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

Report IEA - PVPS T1 - 10 : 2001

TRENDS IN PHOTOVOLTAIC APPLICATIONS in selected IEA countries between 1992 and 2000

Foreword

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD). The IEA carries out a comprehensive programme of energy co-operation among its 26 member countries and with the participation of the European Commission.

The IEA Photovoltaic Power Systems Programme (IEA-PVPS) is one of the collaborative research and development agreements within the IEA and was established in 1993. The mission of the programme is to "enhance the international collaboration efforts through which photovoltaic solar energy becomes a significant renewable energy source in the near future". The underlying assumption is that the market for photovoltaic systems is in the process of expanding from the present niche markets of remote applications and consumer products, to the utility market, through building-integrated and other distributed and centralised PV generation systems.

In order to achieve this, the 20 countries participating in the programme and the European Commission have undertaken a variety of joint research projects in applications of photovoltaic power systems.
The overall programme is headed by an Executive Committee, comprising one representative from each country, which designates distinct 'Tasks', which may be research projects or activity areas. This report has been prepared under Task 1, which facilitates the exchange and dissemination of information arising from the overall IEA-PVPS Programme.

"This International Survey Report (ISR) constitutes the 6th issue in a series of consecutive reports published since 1995 by the IEA PVPS Programme. These reports have gradually focused on the most important facts and figures of photovoltaic markets and industry as well as the initiatives in IEA countries. The ISR is now established as a reference source to all those interested in these figures. Due to the rapid expansion of the photovoltaic market and the widespread use of this report, IEA PVPS sets particular priority in publishing the results as early as possible on an annual basis. We are proud to systematically track the important trends in the deployment of this new and sustainable energy technology. This report will fulfil its mission if it can contribute to attract even more interest towards photovoltaics and thereby form an important information tool."

Stefan Nowak
Chairman IEA-PVPS Programme

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This report has been prepared under the supervision of Task 1 by Dr Alan Taylor of Halcrow Group Ltd (GBR) on the basis of National Survey reports prepared by Task 1 experts and their assistants (see annex A). The report has been funded by the IEA-PVPS Common Fund and has been approved by the IEA-PVPS Executive Committee.

To obtain additional copies of this report or information on other IEA-PVPS publications contact the IEA-PVPS website at www.iea-pvps.org.

September 2001

1 Introduction

1.1 Survey report scope and objective

As part of the PVPS programme, annual surveys of photovoltaics (PV) power applications and markets in the 20 participating countries[1] are carried out. The objective of the survey reports is to present and interpret trends in both PV systems and components being used in the PV power systems market, and changing applications for these products within that market. These trends are analysed in the context of the business, policy and non-technical environment in the reporting countries.

The survey report is not intended to serve as an introduction to PV, nor as a policy document. It is prepared to assist those responsible for developing the business strategies of PV companies and to aid the development of medium term plans for electricity utilities and other providers of energy services. It also provides guidance to government officials responsible for setting energy policy and preparing national energy plans.

This report presents the results of the sixth international survey. It provides an overview of PV power systems applications and markets in the reporting countries at the end of 2000 and analyses trends in the implementation of PV power systems between 1992 and 2000.

1.2 Survey method

Data were drawn from national survey reports[2], which were supplied by representatives from each of the participating countries. A list of the national representatives is given in annex A.

The scope of the reports is limited to PV applications with a peak rating of 40 W or more. Most national data supplied were accurate to ±10 %, although data on production levels and system prices vary depending on the willingness of the relevant national PV industry to provide data for the survey.

The data were collated, and this report prepared, by the Technical Writer. The report has been reviewed by the national representatives to ensure the accuracy of the data used and approved by the IEA-PVPS Executive Committee.

1.3 Definitions, symbols and abbreviations

For the purposes of this report, standard ISO symbols and abbreviations are generally used. The electrical generation capacity of PV cells or systems is given as watt peak (W), which is the peak power of a PV module or system under standard test conditions of 1 000 Wm^{-2} irradiance, 25 ^{0}C junction temperature and solar reference spectrum AM 1.5. The term PV system includes the modules, inverters, batteries and all associated installation and control components as appropriate. When presenting the installed PV capacity only systems with a capacity of 40 W or more have been included. The currency used in this report is the US Dollar (USD), and the exchange rates used for the conversion from national currencies are given in annex B.

[1] *Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), Finland (FIN), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), the Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), the United Kingdom (GBR), the United States of America (USA)*

[2] *A survey report was not available from Austria or Spain and so the most recent data were used where appropriate.*

2 Implementation of Photovoltaic Systems

2.1 Applications for photovoltaics

Four primary applications for PV power systems are identified in this survey:

Off-grid domestic systems provide electricity to isolated households in remote areas. They provide electricity for lighting, refrigeration and other low power loads and have been installed worldwide, particularly in developing countries, where they are often the most appropriate technology to meet the energy demands of isolated communities. Off-grid systems generally offer an economic alternative to extension of the utility electricity distribution grid at distances of more than 1 or 2 kilometres from existing power lines.

Off-grid non-domestic installations were the first commercial application for terrestrial PV systems. They provide power for a wide range of applications, such as telecommunications, water pumps, vaccine refrigeration, navigation aids, aeronautical warning lights and meteorological recording equipment. These are applications where small amounts of power have a high value, and thus PV is price competitive.

Grid-connected distributed

PV systems are a relatively recent application where a PV system is installed to supply power to a building or other load that is also connected to the utility grid. The systems usually feed electricity back into the utility grid when electricity generated exceeds the building loads. These systems are increasingly integrated into the built environment and are likely in the future to become commonplace. They are used to supply electricity to dwellings, commercial and industrial buildings, and are typically between 1 kW and 100 kW in size. There are a number of advantages for these systems: distribution losses are reduced because the systems are installed at the point of use, no extra land is required for the PV systems, costs for mounting systems can be reduced, and the PV array itself can be used as a cladding or roofing material as 'building integrated PV' (BIPV). Compared to an off-grid installation, system costs are lower as energy storage is not required, a factor that also improves system efficiency.

Grid-connected centralised

systems have been installed for two main purposes: as an alternative to centralised power generation from fossil fuels or nuclear energy, or for strengthening of the utility distribution grid. Utilities in a number of countries were interested in investigating the feasibility of these types of power plants. Demonstration plants have been installed in Germany, Italy, Japan, Spain, Switzerland and the USA, generating reliable power for utility grids and providing experience in the construction, operation and performance of such systems. However, utility interest is now tending to focus on distributed PV plants and few centralised plants have been started since 1996.

2.2 Total photovoltaic power installed

712 MW of PV power had been installed in the reporting countries by the end of 2000. The increase in installed capacity between 1992 and 2000 is shown in figure 1, broken down into the four primary applications for PV power systems. This represents a significant proportion of the worldwide installed PV power, and will be indicative of the global trend.

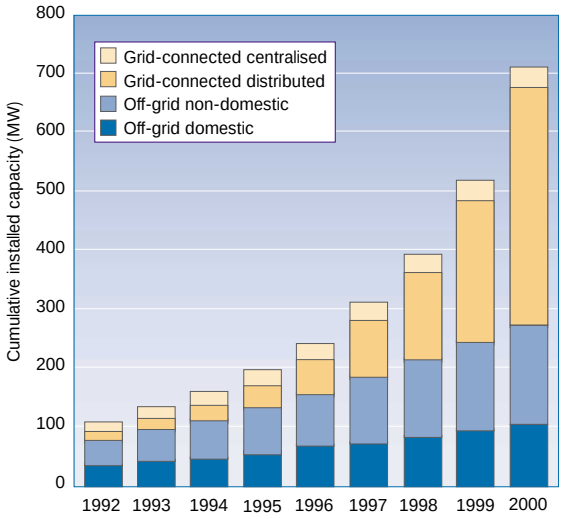

Figure 1 - Cumulative installed PV power by application area in the reporting countries

Between 1992 and 1999 the rate of growth of total installed capacity was between 20 % and 31 % per annum. This rate of increase rose sharply to 37 % between 1999 and 2000. It can be seen from table 1 and table 2 that the majority of this rise is due to the continued dramatic increases in Japan (109 MW) being joined by a significant increase in Germany (44 MW). Indeed it can be seen that of the 192 MW installed in 2000, 80 % was installed in Japan and Germany alone. This continued high rate of installation in Japan promotes the country to that with the highest installed power per capita (2.5 W/capita) above Switzerland (2.1 W/capita).

Figure 2 indicates that until 1998 the greatest percentage of PV systems installed in the reporting countries were for off-grid applications. However from 1999, the greatest percentage of installed PV systems were grid-connected. This is still true in the majority of the reporting countries and figure 3 illustrates that in Mexico, Norway, Finland, Canada, Sweden, Israel, France and Korea over 90 % of the total installed capacity is off-grid. This encompasses a wide range of applications. In Canada, Finland, Norway and Sweden, the majority of off-grid PV systems are used for seasonal and recreational buildings and remote cabins. In France, Israel and Mexico, PV is used as a strategy for rural electrification. In Australia, Korea and Japan most off-grid systems are non-domestic and provide power for pumps, agriculture, traffic signals and telecommunications. For remote areas PV provides a commercial alternative to diesel and central grid supplies.

However the overall trend is a rapid increase in the proportion of PV power that is grid-connected. In 1992 only 29 % of the cumulative installed capacity was connected to the grid, by the end of 2000 this had reached 61 %. This is due almost entirely to a proliferation of grid-connected distributed systems as there was only approximately 1.4 MW of grid-connected centralised PV installed in 2000.

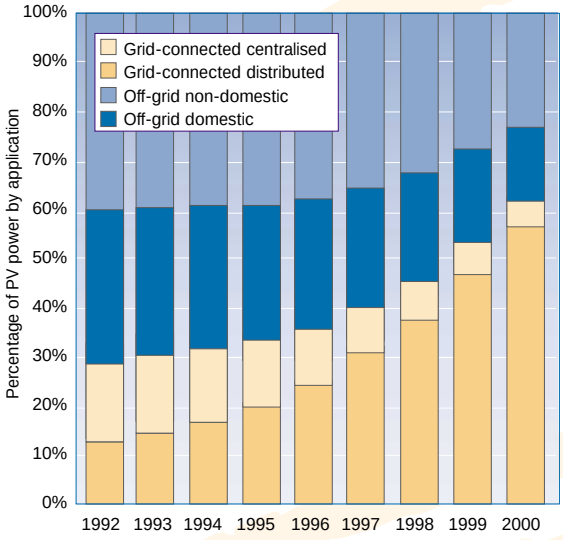

Figure 2 - Percentage of grid-connected PV power in the reporting countries (centralised and distributed)

The rapid rise in grid-connected distributed applications is driven mainly by the large, government or utility supported programmes in Japan, Germany, the USA and the Netherlands, which generally focus on PV in the urban environment. Although not significant in absolute terms, it is worth noting that grid-connected, distributed, installed capacity is

actually expanding most rapidly in Norway (733 % growth, 44 kW installed), Finland (106 % growth, 50 kW installed) and the UK (105 % growth, 770 kW installed), which are countries with relatively few initial PV installations of this type.
The rate of growth in countries such as France (74 % growth, 259 kW installed), where PV has been generally been used for off-grid applications, is also similar to that experienced in Germany (74 % growth, 42 000 kW installed) and the Netherlands (63% growth, 3 370 kW installed), where grid-connected applications dominate.

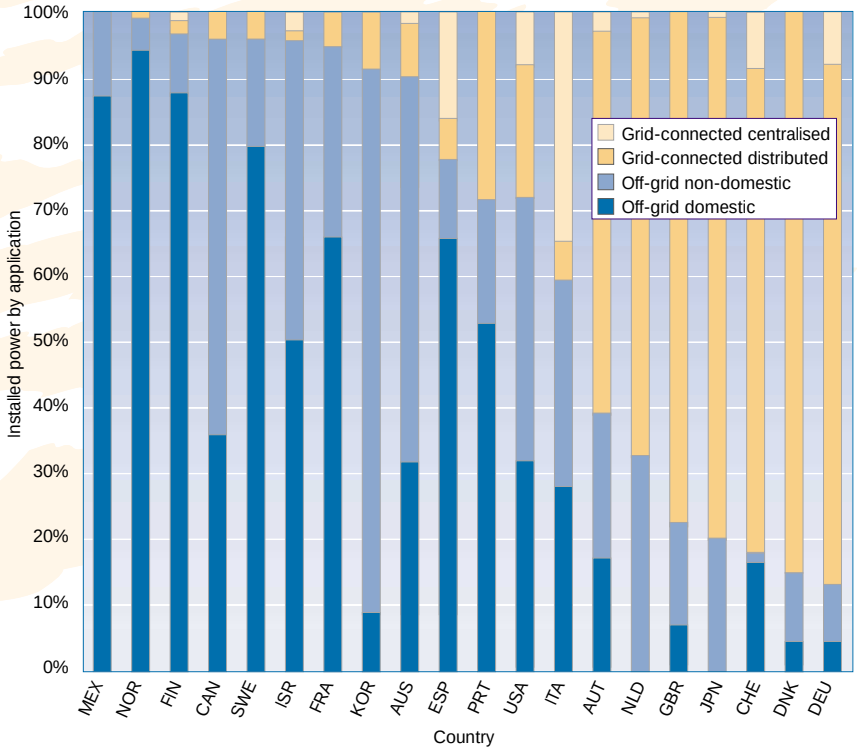

Figure 3 - Installed power by application in the reporting countries in 2000

Table 1 - Cumulative installed PV power as of the end of 2000

Country	Off-grid domestic kW	Off-grid non-domestic kW	Grid-connected distributed kW	Grid-connected centralised kW	Total kW	Total installed per capita w/Capita	Power installed in 2000 kW
AUS	9 110	17 060	2 390	650	**29 210**	1.52	3 890
AUT	593	820	2 119	140	**3 672**	0.45	
CAN	2 536	4 303	305	10	**7 154**	0.23	1 328
CHE	2 390	210	11 220	1 480	**15 300**	2.11	1 900
DNK	50	155	1 255		**1 460**	0.27	390
DEU	4 200	9 600	89 900	10 100	**113 800**	1.37	44 300
ESP	5 900	1 100	600	1 480	**9 080**	0.23	
FIN	2 225	230	67	30	**2 552**	0.49	250
FRA	7 416	3 307	608		**11 331**	0.19	2 210
GBR	121	302	1 506		**1 929**	0.03	798
ISR	221	200	6	14	**441**	0.08	40
ITA	5 240	5 890	1 155	6 715	**19 000**	0.33	520
JPN	550	61 350	252 700	2 900	**317 500**	2.51	108 900
KOR	316	3 288	356		**3 960**	0.08	501
MEX	12 167	1 833	9		**14 009**	0.14	1 087
NLD		4 080	8 499	180	**12 759**	0.80	3 564
NOR	5 650	330	50		**6 030**	1.35	304
PRT	484	176	268		**928**	0.09	84
SWE	2 216	465	124		**2 805**	0.32	221
USA	43 500	55 200	28 100	12 000	**138 800**	0.50	21 500
Total	**104 885**	**169 899**	**401 237**	**35 699**	**711 720**	**0.73**	**191 787**

Table 2 - Cumulative installed PV power: historical perspective

Country	Cumulative installed PV Power kW								
	1992	1993	1994	1995	1996	1997	1998	1999	2000
AUS	7 300	8 900	10 700	12 700	15 700	18 700	22 520	25 320	29 210
AUT	524	768	1 062	1 360	1 739	2 208	2 861	3 672	3 672
CAN	960	1 240	1 510	1 860	2 560	3 380	4 470	5 826	7 154
CHE	4 710	5 775	6 692	7 483	8 392	9 724	11 500	13 400	15 300
DNK		85	100	140	245	422	505	1 070	1 460
DEU	5 619	8 900	12 440	17 790	27 890	41 890	53 900	69 500	113 800
ESP	3 950	4 649	5 660	6 547	6 933	7 100	8 000	9 080	9 080
FIN	914	1 034	1 156	1 288	1 511	2 042	2 170	2 302	2 552
FRA	1 751	2 051	2 437	2 940	4 392	6 118	7 631	9 121	11 331
GBR	173	266	338	368	423	589	690	1 131	1 929
ISR	100	120	150	180	210	265	308	401	441
ITA	8 480	12 080	14 090	15 795	16 008	16 709	17 680	18 480	19 000
JPN	19 000	24 270	31 240	43 380	59 640	91 300	133 400	208 600	317 500
KOR	1 471	1 631	1 681	1 769	2 113	2 475	2 982	3 459	3 960
MEX	5 400	7 100	8 820	9 220	10 020	11 022	12 022	12 922	14 009
NLD	1 270	1 641	1 963	2 400	3 257	4 036	6 480	9 195	12 759
NOR	3 800	4 100	4 400	4 650	4 900	5 150	5 404	5 726	6 030
PRT	169	219	258	336	424	527	648	844	928
SWE	800	1 040	1 337	1 620	1 849	2 127	2 370	2 584	2 805
USA	43 500	50 300	57 800	66 800	76 500	88 200	100 100	117 300	138 800
Total	**109 891**	**136 169**	**163 834**	**198 626**	**244 706**	**313 984**	**395 641**	**519 933**	**711 720**

2.3 Major projects, demonstration and field test programmes

Although off-grid PV applications account for the majority of the total installed power in many countries there are few major projects or demonstration programmes in this sector. This may be the result of the off-grid market being relatively well established and, by its nature, installed systems tend to be small and isolated. Thus, the majority of the projects and programmes reported below are for grid-connected systems.

The CitiPower Solar Pioneers Program in **Australia** is an example of a project that aims to demonstrate the viability of residential and commercial grid-connected PV systems, to accelerate uptake and increase sales volumes by enabling utility customers to participate in greenhouse gas reduction activities. Funded by an electricity retailer and the Australian Government, the programme installed 50 systems in 2000 with a total capacity of 58 kW. A nation-wide programme, the PV Rebate Program, aimed to encourage the development and use of building integrated PV. This resulted in over 2 600 systems being installed in 2000, amounting to 2.8 MW, and 81 % of systems were on off-grid buildings. A large urban centre redevelopment, at Kogarah, is Australia's largest solar power supplemented medium-density residential development, and includes at least 160 kW of BIPV systems.

In **Canada** there were a number of key demonstration projects supported by the Climate Change Action Fund in 2000. Innovative BIPV projects were installed as part of the glass façades of existing and new office buildings in Vancouver. Other demonstration projects in Waterloo and Victoria aimed to demonstrate the domestic integration of PV into 'Solar Homes'. The Greenpeace 'Solar Pioneer' programme drew to a close, and a corresponding drop in the grid-connected market followed. Nevertheless, there is evidence of a sustained market for off-grid systems that are not subsidised with 1.3 MW installed in 2000.

Renewable energy technologies have high priority in the national **Danish** energy plan, Energy 21, and its associated follow-up measures. One of the most high profile projects has been the 300-rooftop project, Sol-300. This has delivered 750 kW of PV systems on

existing residential houses. The project was launched early 1998 and all installations were completed by the end of 2000. About 80 % of the financing of this project came from a Public Service Obligation placed on electricity utilities.

In **Finland**, two high profile projects have been implemented by the dominant utility Fortum to build experience in two distinct sets of applications. The first, at Citymarket Lielahti, saw the installation of a low-cost roof-mounted 39 kW installation with the aim of gaining experience of grid-connected systems in the built environment. The second, at the Helsinki University of Technology was a more modest 7 kW BIPV system to investigate PV façade elements that also provide building shading.

The emphasis in **France** continues to be for off-grid systems as part of a rural area electrification strategy. The successful 'FACE' programme continues and has to date delivered just under 1 MW of capacity in continental France. In the overseas Dèpartements, tax exemptions and direct grants continue to deliver around 1.4 MW per annum.

The success of the combination in **Germany** of the 100 000 roofs programme, the Renewable Energy Law and earlier initiatives is illustrated by a significant increase in numbers of grid-connected distributed systems, with 40 MW installed in 2000. The average size of PV plant in requests for support has grown from 2.5 kW in 1999 to 5.2 kW in 2000, an illustration of the financial attractiveness of PV plant under these measures. At the Expo 2000 World Fair in Hanover, over 20 exhibits featured innovative PV systems. Other examples are: a 1 MW PV plant in Herne, the solar-cell factory of Shell Solar in Gelsenkirchen and the SolarFabrik in Freiburg (65 kW). Within the framework of the relocation of the German government to Berlin, over 760 kW of PV was installed on 14 sites, including 38 kW on the new roof of the Reichstag and 123 kW of a-Si modules on the roof of the Paul Löbe Haus. The 'Sun at School' programme is still active and a new programme, '600 Parishes for Solar Energy', was initiated.

The market in **Israel** is limited to off-grid installations, temporary projects (such as outdoor music concerts) and the Bedouin sector. One interesting project is a hybrid refrigeration system for a remote Bedouin home, sponsored by the Israel Diabetic Association, to bring electricity to the family of a boy suffering from acute diabetes. The system itself consists of 106 W of PV plus a 400 W wind generator, powering a medicine refrigerator and home lighting.

The **Italian** authority, ENEA, has been carrying out tests to evaluate the long-term effects of high levels of PV penetration on small isolated grids. In a framework of activities to precede a large scale Italian rooftop programme, a further ten small systems were installed on private and municipal building across the country in order to evaluate architectural and technical integration aspects.

Japan continues to make dramatic progress in implementing significant PV capacity through a range of research demonstration and market measures. The main programmes implemented in 2000 were:

a) PV Field Test Project for Public Facilities,
b) Residential PV System Dissemination Programme,
c) PV Field Test Project for Industrial Use,
d) Introduction and Promotion of New Energy at the Regional Level,
e) Financial Support Project for Entrepreneurs Introducing New Energy,
f) Support Project for Local Efforts to Introduce New Energy, and g) Eco-school Promotion Pilot Model Project.

Each of these programmes provides targeted support in a number of sectors and most provide a direct subsidy towards the installation costs of the equipment.

KEMCO, the **Korean** Energy Management Corporation, has managed three grid-connected demonstration projects during 2000: a 10 kW system at Chungbuk Provincial University, a high profile 6 kW BIPV project, and a scheme to demonstrate grid-connected residential PV systems.

There is no defined PV programme in **Mexico**, with most x¸ejects being carried out in the context of more general programmes for poverty alleviation and agricultural development. Whilst early projects were lead by federal agencies, this role is now being increasingly played by state and local governments. Secondary to the domestic sector, the telecommunication industry has embraced PV for purely commercial reasons, with many remote sites now featuring PV systems and PV hybrid systems. Some of these sites are substantial, with up to 16 kW of PV installed at a single location.

In the **Netherlands** the year 2000 has been characterised by various large-scale private PV applications. Examples are 'Solaris', 'Sunpower' and 'PV Zonneklaar'. These projects, mostly co-ordinated by several energy companies, are now under construction. They are commonly aimed at private house-owners to buy or lease small (less than 400 W) PV-systems. All of these PV-systems are connected to the grid and their installed capacity in 2000 is estimated at 970 kW.

Two demonstration projects opened in **Norway** in June 2000. The first is a 20 kW education and research facility at the Agder College using one multi-crystalline and one amorphous silicon line to electrolyse water to produce hydrogen. The second, also at a university (Trondheim), aims to study the aesthetic integration of PV into large existing buildings. In this project, 192 m^2 of modules are installed in a glass curtain façade of 450 m^2.

Like France, the potential for providing cost effective sustainable electrification of remote communities in **Portugal** provided the impetus behind the development of three hybrid (PV/wind/diesel) mini grids in the Ourique region. The main high profile grid-connected initiative was the latest stage of the BP Sunflower project, which installed modules on five additional petrol station canopies in 2000 (taking the total capacity installed to about 251 kW).

Very little development was reported in **Sweden** during 2000, although plans are advancing for around 80 kW of BIPV to be integrated in an 8 000-apartment housing development at Hammarby-Sjöstad on the outskirts of Stockholm.

A further 10 PV demonstration projects were started in **Switzerland** in 2000, joining the existing 33. In these new projects, the main area of interest was in the technology development area, with activities including inverter technology, combined noise-protection and PV, measurement campaigns, quality assurance and planning aids. An interesting new concept in BIPV is the provision of thermally insulated commercial roofing and façade PV elements. Work continues on solar roof tiling, with an emphasis on robustness and ageing factors as well as mounting and cabling. Successful tests of a communication system for the monitoring and control of inverters in decentralised configurations has led to the implementation of a commercial 250 kW project featuring the use of LON nodes for the collection of data and the supervision of the installation's 68 inverters. A new variant of combined motorway noise-barrier and PV installation was commissioned in 2000 that allows rapid on-site installation using prefabricated wooden elements fitted with PV modules.

Implementation of the **United Kingdom's** Field Trial of PV systems in the domestic sector commenced in March 2000. The field trial is supporting the installation and monitoring of clusters of systems on new-build housing developments or major domestic refurbishment projects. The overall objective is to use the design, construction and monitoring of the installations as a learning opportunity for utilities, building developers and other key players. The four-year Scolar Programme, which aimed to equip schools with grid-connected PV systems, drew to a close in 2000. In total, approximately 80 systems have been installed to date, amounting to some 50 kW, with over half of this coming online in 2000. The energy company BP continued to install significant grid-connected capacity at its petrol filling stations and at a conference centre in London making it the biggest user of PV in the UK with just under 1 MW installed.

Major projects in the **USA** during 2000 consisted of the continuation of the existing projects and some new initiatives. The Utility PhotoVoltaic Group (UPVG) promoted competitive procurement strategies, with utilities teaming with customers to bid for the installation of around 1 MW of systems with partial financial support (about 25 %) from the US Department of Energy. In Sacramento, the initiation of the Pioneer II project, offering PV systems for sale at subsidised prices, achieved the installation of 0.5 MW in 2000 and, together with the existing Pioneer I scheme, is aiming for 5 MW to be installed between 1999 and 2004. Also in California, the State is offering cash rebates (3 USD/W) to residential and commercial customers that install grid-connected systems on investor-owned utility grids. This program installed between 0.6 and 0.8 MW in 2000. Further refinement and definition of the Million Solar Roofs Initiative has been undertaken, with commitments for partnerships for new installations and projects.

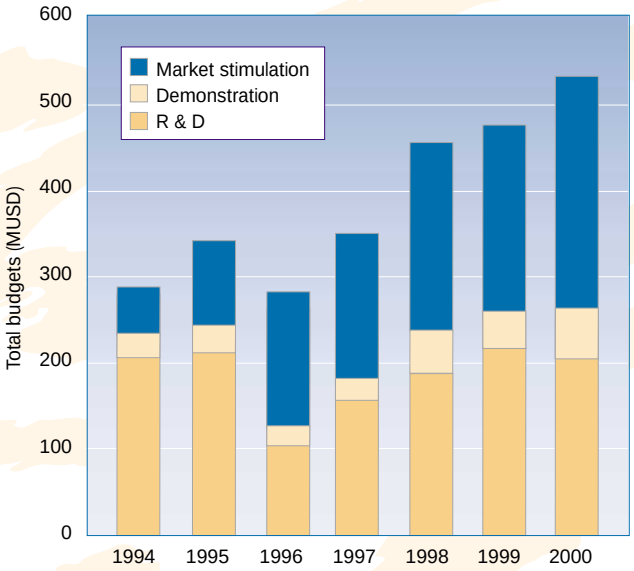

Figure 4 Budget breakdown for market stimulation, demonstration and R&D between 1994 and 2000

2.4 Budgets for market stimulation, R&D and demonstration

Figure 4 shows, that the rapid growth in the rate of installation of PV capacity has been supported by a significant growth of 26 % in the National, Federal and State budgets for market stimulation, research development and demonstration. However, the budget for the demonstration of technologies remains a small proportion of the total spent in this area, at about 11 % overall. This trend is fairly constant between all countries, with market stimulation projects now overtaking that provided for research and development (at 51 % and 38 % respectively).

Where available, the 2000 budget for the reporting countries is shown in table 3[3]. This information is also shown in figure 5 on a per capita basis, and illustrates the relative contribution made by Switzerland, Japan and the Netherlands in funding research, development and supporting market stimulation initiatives. However, significant increases in allocated budgets were also reported in the UK (77 %), USA (80 %), Australia (194 %) and Korea (362 %).

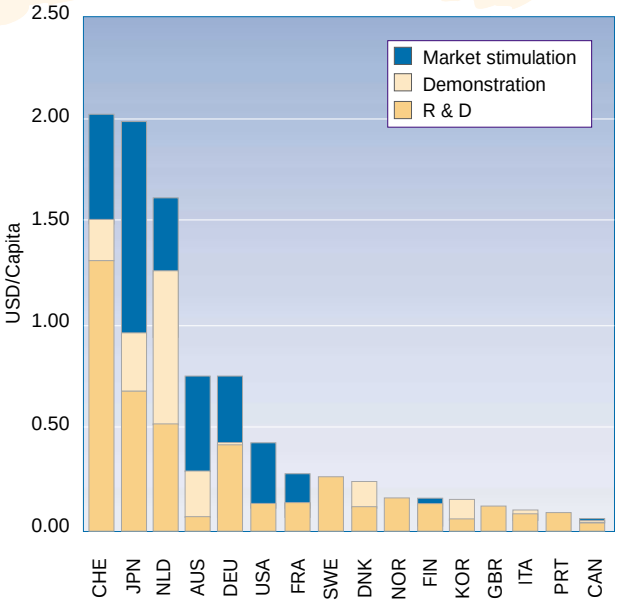

Figure 5 - Per capita budget for R&D, demonstration projects and market stimulation in selected reporting countries

Table 3 - Budget for R&D, demonstration and market stimulation in 2000

Annual Budget, in MUSD																	
Country	**AUS**	**CAN**	**CHE**	**DNK**	**DEU**	**FIN**	**FRA**	**GBR**	**ISR**	**ITA**	**JPN**	**KOR**	**NLD**	**NOR**	**PRT**	**SWE**	**USA**
R&D	1.37	0.98	9.64	0.66	35.09	0.69	7.78	6.79	0.05	4.87	85.68	2.06	8.16	0.72	0.78	2.30	35.00
Demonstration	4.10	0.16	1.31	0.60	0.46	0.01			0.04	0.32	36.56	5.09	11.84			0.02	
Market stimulation	9.02	0.36	3.75		26.51	0.09	8.32		0.03		129.28		5.45				84.60
Total	**14.48**	**1.50**	**14.70**	**1.26**	**62.06**	**0.79**	**16.10**	**6.79**	**0.12**	**5.19**	**251.52**	**7.15**	**25.45**	**0.72**	**0.78**	**2.32**	**119.60**

[3] *The boundaries of what constitutes 'research', 'development', 'demonstration' and 'market stimulation measures' often varies from country to country and are thus not always comparable. Where necessary, estimates of the breakdown between these elements have been made.*

PV technology note

The key components of a photovoltaic system are the photovoltaic cells (interconnected and encapsulated to form a module), the inverter, the battery and charge controller (for off-grid systems) and the mounting structure.

Cells

At present the vast majority of photovoltaic cells are made from silicon. In general, cells are classified as either crystalline (sliced from ingots or castings or grown ribbons) or thin film (deposited in thin layers on a low cost backing).

Crystalline silicon

Single crystal silicon cells are usually manufactured from a single crystal ingot, most commonly grown by the Czochralski method. PV cells made from multicrystalline silicon have now become popular as they are less expensive to produce, although slightly less efficient. Multicrystalline cell manufacture usually begins with a thermal process in which silicon is melted and solidified such a way that crystals are oriented in a predetermined direction. This produces a rectangular ingot of multicrystalline silicon that is then cut into blocks or bricks which are finally sliced into thin wafers that are used to make the cells. One way of eliminating the sawing step is to grow ribbons of multicrystalline silicon that are already wafer thin and the correct width for use as PV cells.

The maximum recorded cell efficiency for crystalline silicon is 24.7 %[4]. Cell efficiencies greater than 25 % have been recorded for cells made from III-V semiconductor material (for example gallium arsenide concentrator systems and for space applications because of their high cost.

Thin film

Thin film modules are constructed by depositing extremely thin layers of photovoltaic materials on a low cost backing such as glass, stainless steel or plastic. Individual 'cells' are formed by then scribing through the layers with a laser. Thin film cells offer the potential for cost reductions. Firstly, material costs are lower because much less semiconductor material is required and, secondly, labour costs are reduced because the films are produced as large, complete modules and not as individual cells that have to be mounted in frames and wired together.

The most fully developed thin film technology is hydrogenated amorphous silicon. This is the material normally used in consumer applications, although it is used, but less frequently, in power modules.
The efficiency of commercial amorphous silicon modules has improved from around 3.5 % in the early 1980's to over 7 % currently. The most efficient modules are made with multiple layers of photovoltaic material, for instance three layer amorphous silicon modules with germanium added to two of the layers (a-Si/a-SiGe/a-SiGe) which have a record cell efficiency of 13.5 %[5]. Other types of thin films can be made using polycrystalline silicon, cadmium telluride (CdTe), and copper indium gallium diselenide (CIGS).

Typical and maximum module and cell conversion efficiencies (at Standard Test Conditions, i.e., 1 000 Wm-2, 25 ^{0}C, solar spectrum AM1.5) are given in the table below for some of the commercially available PV technologies.

Type	*Typical module efficiency %*	*Maximum recorded module efficiency [4] %*	*Maximum recorded laboratory efficiency [4] %*
Single crystalline silicon	*12-15*	*22.7*	*24.7*
Multicrystalline silicon	*11-14*	*15.3*	*19.8*
Amorphous silicon	*5-7*	*-*	*12.7 [6]*
Cadmium telluride	*-*	*10.5*	*16.0*
CIGS	*-*	*12.1[5]*	18.2

[4] *Solar Cell Efficiency Tables, Version 15, M.A.Green, K. Emery, D.L. King, S. Igari, Progress in Photovoltaics: Research and Applications, 8, 187-195 (2000)*
[5] *Alloy with sulphur*
[6] *Unstabilised results*

Module

For crystalline silicon cells, after testing and sorting to match the current and voltage, the cells are interconnected and encapsulated between a transparent front, usually glass, and a backing material. This 'module' is then typically mounted in an aluminium frame. Modules are normally rated between 50 and 200 W, although several manufacturers now offer modules above 200 W.

Inverter

An inverter is used to convert the direct current (d.c.) source (from the module or battery) to alternating current (a.c.). The efficiency of inverters is generally greater than 90 %, when the inverter is operating above 10 % of its rated output, and can peak as high as 96 %. Inverters connected directly to the module (as opposed to through a battery) incorporate a Maximum Power Point Tracker (MPPT), which continuously adjusts the load impedance such that the inverter is always extracting the maximum power from the system.

Inverters fall into two-main categories: self-commutated and line-synchronised. The first can operate independently, being activated solely by the input power source; the line-synchronised inverters are triggered directly from the grid. Utilities require that inverters connected to the grid must contain suitable control and protection to ensure that systems are installed safely and do not adversely affect the power quality.

Traditionally, one inverter was used for the whole array. Now separate inverters may be used to connect each 'string' of modules or even mounted on the back of individual modules ('a.c. modules'). String inverters and a.c. modules are likely to be increasingly used in the building-integrated PV market because they permit easy system expansion, independent operation and easier installation.

Battery

For off-grid systems a battery is used to provide energy storage. Nearly all batteries used for PV systems are of the lead-acid type (with a small quantity of antimony to reduce self-discharge). Nickel-cadmium batteries are also suitable and have the advantage that they cannot be overcharged or discharged, but are considerably more expensive.
All PV batteries are deep-cycle i.e. designed to be discharged down to 50 % or more without damage so that they can supply power over a long period of time (in contrast to a car battery, for example, which is usually only discharged down to 3 to 5 %).
The lifetime of a battery varies depending on factors such as how it is used, how it is maintained and charged, and temperature, but is typically between 5 and 10 years.

Charge controller

The primary function of a charge controller (or regulator) is to maintain the battery at the highest possible State Of Charge (SOC) and provide the user with the required quantity of electricity, while protecting the battery from deep discharge (by the loads) or extended overcharge (by the PV array). Most charge controllers operate via voltage regulation set points. However, as voltage is not representative of the true SOC, new algorithms are being developed to evaluate the state of the battery, based on Ah or combined VAh monitoring.

Additional features such as battery temperature or wire compensation, meters and alarms can enhance the ability of the charge controller to meet the load demand and extend battery lifetime. Other functions such as MPPT, d.c./d.c. conversion, anti-theft protection, load management, pre-payment and data logging can also now be built into the charge controller.

Mounting structure

With the rapid growth of grid-connected distributed systems, a wide range of products have been developed for installing PV modules on buildings. These include mounting structures for PV facades, roof profiles, flat roofs and even 'PV tiles' that can be used to replace conventional roof tiles. New products are addressing the need for ease of integration into the building envelope and aesthetic appeal.

3 The Photovoltaic Industry

3.1 Photovoltaic cell and module production

The total module production reported in 2000 was in the order of 238 MW. This figure includes production for off-grid power applications of smaller than 40 W, but generally not for small consumer applications. It is estimated that this figure accounts for 85 % to 90 % of modules produced worldwide. Figure 6 illustrates the rate of growth of module production, and also indicates an apparent low level of utilisation (62 %) of the reported 382 MW of production capacity available. This effect is likely to be a reflection of a rapidly growing industry in which bottlenecks in component supply chains can be expected and for which facilities are in the process of being built, but are not fully operational, at the time of reporting.

Total module production increased by just under 42 % between 1999 and 2000. This growth took place primarily in Japan, where module production increased

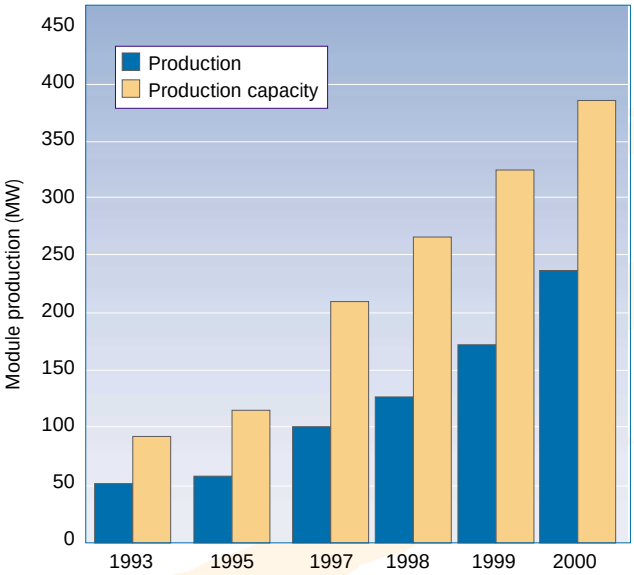

Figure 6 - PV module production and module production capacity between 1993 and 2000

Table 4 - PV cell and module production in 2000 by world region

Region	Cell Production	Module Production				Module Production Capacity
	MW	Crystalline MW	Amorphous MW	Other/ Unknown MW	Total MW	MW
USA	75	43	7	6	**56**	91
Japan	128	115	8	12	**136**	195
Europe	37	23	2	16	**41**	87
Other	4	6			**6**	9
TOTAL	243	187	17	34	**238**	382

by 60 % between 1999 and 2000, a similar rate of increase to the previous year, with two companies (Kyocera and Sharp) producing over 40 MW each. It can be seen from table 4 that over 57 % of all the modules produced in 2000 were from Japan and this trend looks set to continue with Japanese capacity planned to exceed 200 MW in 2001. The USA accounts for 31 % of all cells manufactured, but only 24 % of the modules, since it exports a proportion of cell production to module manufacturers elsewhere.

Module production remains based, predominantly, on crystalline silicon technologies, of which approximately 60 % is multi-crystalline and 40 % is single crystalline. Traditionally used for consumer products, amorphous silicon has still to make a significant impact on the PV power market, and production fell by over 20 % during 2000.

Table 5 lists the key PV product manufacturers in each of the reporting countries. The manufacturers can be divided into two broad categories: firstly, those who purchase ready made cells and assemble them into modules; secondly, vertically integrated manufacturers who manufacture their own cells and modules. Amorphous silicon manufacturers are normally

vertically integrated production lines, as the cell and module are usually built in the same process.
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Amorphous silicon manufacturers are normally vertically integrated production lines, as the cell and module are usually built in the same process.

A number of countries that have little, or no, module manufacturing capacity are active in other areas. For example, Isovolta/Werndorf (Austria) produce and export approximately 50 % of the world demand for tedlar for PV modules. Crystalox (UK) and ScanWafer (Norway) are major exporters of multi-crystalline silicon ingots and wafers and Automation Tooling Systems (Canada) have developed and marketed automated photovoltaic cell and custom manufacturing module lines. In Switzerland, two companies have a big market share for wire saws for cell production (Meyer & Burger and HCT Shaping Systems).

Table 5 - PV product manufacturers in the reporting countries

Country	Company	Cell Production (MW)	Module Production (MW)	Production Capacity (MW)	Technology Type	Additional Information
AUS	BP Solar	0.1	2.1		sc-Si	Consolidated production in BP Solar's Sydney facility is expected to reach 15 MW by the end of 2001, with capacity to expand to 40 MW
		4	3.4	7	mc-Si sc-Si & mc-Si	
	Sustainable Technologies International				Titania Dye	Titania Dye Sensitised Solar Tile and Wall Panel manufacturing facility expected to open during 2001 with a capacity of 0.5 MW
CAN	ICP Global				sc-Si, mc-Si	Started production in October 2000 using cells and components purchased on world market. Aiming for a production capacity of 2 MW in 2001
CHE	Star Unity		0.02	0.1	sc-Si	Import cells and integrate them into roof tiles ('Sunny Tile')
	Atlantis Solar Systems AG		0.4	1.2	sc-Si	Produce custom laminates using imported cells and 'Sunslate' roofing shingles. Also have production facilities in Germany & USA of 1 MWp capacity.
	VHF Technologies				a-Si	New entrant producing thin film products on a plastic substrate. Full production expected during 2001
DNK	Gaia Solar		0.09	0.33	mc-Si,sc-Si	Produce modules (27 - 150 W) from imported cells. Small production increase in 2000
DEU	More than 30 companies	15.9	16.1	34	mc-Si, sc-Si, EFG, a-Si, CIS	In Germany there are 13 companies manufacturing modules with outputs in the range 200 - 4600 kW, 2 companies at the pre production stage and about 15 companies producing modules for specific applications (e.g. roof tiles)

Country	Company	Cell Production (MW)	Module Production (MW)	Production Capacity (MW)	Technology Type	Additional Information
ESP	Atersa		1	1.5	sc-Si	
	BP Solar Espana	4.4	4.6	10	sc-Si	
	Isofoton	0.64	3.37	5	sc-Si	
FRA	Photowatt International	8.3	4.7	7	mc-Si	Manufactures multicrystalline ingots, wafers and modules with a total cell manufacturing capacity of 20 MW. Wide range of products and innovating in ingot casting & wire-sawing techniques.
	Free Energy Europe		0.45	0.5	a-Si	Manufacturer of thin film module products for applications up to 100 W
GBR	Intersolar		1.6	3	a-Si	Production capacity increased from 2.5 MW per annum in 1999 to 3 MW in 2000 and a large proportion of its production is exported. Module production figure includes cell only production for a variety of consumer products
ITA	Eurosolare	0.2	0.2	3	sc-Si	Module manufacturing process is fully integrated with a high degree of automated processes and company operations range from original R & D to turnkey supply
		2.6	2.2		mc-Si	
	Helios Technology	2.3	2.1	2.5	sc-Si	Little change in production over the last year
JPN	Kyocera	44	42	70	mc-Si	Module production has increased from 30.2 MW (1999). Production capacity increase to 90 MWp planned for 2001. New developments include next generation thin film mc-Si, hybrid light/thermal systems, and building material integrated products.
	Sharp	10	10	10	sc-Si	Commercialisation of residential PV system with mc-Si cells of 16% efficiency and multi power conditioner available for various layouts of PV modules. Plans to double mc-Si production in 2001.
		40.3	40.3	44	mc-Si	
		0.1	0.1	0.1	a-Si	
	Sanyo Electric	4	4	5	a-Si	Plans to increase a-Si/sc-Si module production to 28 MW in 2001. Have commercialised a-Si/sc-Si bifacial module and plan to develop modules spcifically for high rise buildings.
		11	11	12	a-Si/sc-Si	
	Canon	1.41		10	a-Si	No change in cell production in 2000
	Showa Shell Sekiyo		2.9	6	sc-Si	Development of roofing material integrated modules continues, but has no plans for any additional capacity.
	Mitsubishi Electric	12	12	15	mc-Si	Production capacity of 25 MW planned for 2001, with development of more building materials integrated products, including transparent modules.
	Kaneka	3	3	10	a-Si	Commercialisation of roof integrated systems and further development of high efficiency thin film hybrid type Si products

Country	Company	Cell Production (MW)	Module Production (MW)	Production Capacity (MW)	Technology Type	Additional Information
JPN	Matsushita Battery	1.2	1.2	1.5	CdS/CdTe, mc-Si	Products mainly for consumer use
	MSK		7	8	mc-Si	Commercialisation of ceramic roof tile integrated modules.
			1	1	sc-Si	
	Matsushita Seiko	1	1	1.5	a-Si	Matsushita Seiko took over the solar business of Air Water (former Daido Hoxan) in April 2000.
		0.2	0.2	1	sc-Si	
KOR	LG Industrial System		0.16	0.5	sc-Si	Manufactures a range of modules using Siemens cells imported from USA
	Samsung Electronics		0.45	1	mc-Si	Doubled its production capacity in 2000 and manufactures five types of modules using BP Solar cells.
	Haesung Solar		0.04	0.5	sc-Si	Currently only manufactures small (up to 50 W) modules but has plans to produce larger modules (200 W) in near future
NLD	Shell Solar Energy	2.2	2.2	7	mc-Si	No significant expansion in capacity reported, but new co-operation agreement with Siemens is expected to bring forward development of new CIS technology
	AKZO Nobel					Production is planned, but is currently still in R & D phase
	Logic Electronics				mc-Si	Facilities currently under construction, with production scheduled to start in 2001
NOR	ScanCell			8	mc-Si	Plant currently under planning/ construction
SWE	GPV		1	2	mc-Si	Planned expansion of capacity in 2000 was delayed until 2001, when a capacity of around 15 MW is expected
			1	2	sc-Si	
USA	Siemens Solar Industries	28	20	30	sc-Si	Pilot production of CIS product began in 1998; large-area modules with efficiencies > 12 % have been produced.
			0.5	3	CIS	
	BP Solar	17	15	20	mc-Si	Offer modules from 33-200 W. Production of mc-Si modules increased 25 % and that of a-Si modules by 75 %
		3.5	3.5	6	a-Si	
	AstroPower	17	8	20	sc-Si	Most of AstroPower's production is sold as cells, although standard power modules are also produced. The Silicon Film product is still under pilot production.
		1	1	1	Si film	
	Solec International					Solec now producing only n-type slices for Sanyo aSi/Ssi cells production in Japan.
	ASE Americas	4	4	5	EFG-Si	Completed a major expansion of their plant in 1998 and produce large (200-300 W) modules as standard as well as significant quantities of cells for module manufacture in Germany.

Country	Company	Cell Production (MW)	Module Production (MW)	Production Capacity (MW)	Technology Type	Additional Information
USA	United Solar Systems Corp. (USSC)	3	3	4.5	a-Si	Production in 5 MW triple-junction a-Si plant began in 1997. In addition to standard power modules, produce two building-integrated products. In a Joint venture with Bekaert of Belgium, USSC are now building a 25 MW a-Si facility in Michigan
	Evergreen Solar	0.2	0.2	0.5	String ribbon	Pilot line at present, although full production expected in late 2001
	Other	0.8	0.5	1	Various	Other companies nearing production: Ebara Solar, First Solar, Energy Photovoltaics, plus companies specialising in concentrator cells.
	TOTALS	243.35	238.58	382.23		

Key:

sc-Si	single crystal silicon	a-Si	amorphous silicon
mc-Si	multicrystalline silicon	CIS	copper indium diselenide
EFG	edge fed growth silicon	CdTe	cadmium telluride

3.2 Balance of system component manufacturers and suppliers

A large industry exists manufacturing balance of system components such as inverters, batteries and battery charge controllers, d.c. switch-gear and array support structures. The PV Technology Note provides a brief technical description of these components.

The price of grid-connect inverters has shown small reductions in 2000. Typical prices are between 600 to 1 000 USD/kVA for inverters in the range of 1 to 10 kVA, although prices below 500 USD/kVA are reported in the Netherlands. Prices are generally lower for larger inverters and can be as low as 300 USD/kVA for inverters above 100 kVA. Stand-alone inverters also tend to be cheaper since they do not need the additional control and protection functions required for grid-connection and are not, generally, required to produce a pure sine wave output.

In the absence of an international standard for grid-connection, the choice of inverters is largely determined by those manufacturers that comply with the requirements for connection pertinent to a particular country. Many inverters now include a digital output display and data acquisition system connection as standard. Manufacturers in the USA and Germany have developed dual inverters so that grid-connect systems can also be used as a back up for the grid.

Over 150 000 charge controllers manufactured by US suppliers were sold in 2000 and of these over 80 % were exported.

Manufacturers in France and Germany offer charge regulators with prepayment function and integrated battery, providing a portable, easy-to-use system.

3.3 System prices

Prices for entire systems vary widely and depend on a variety of factors including system size, location, customer type, grid connection and technical specification. For example, for BIPV systems the cost of the system will vary significantly depending whether the system is part of retrofit or is integrated into a new building structure. Another factor that has been shown to have a significant effect on prices is the presence of a market stimulation measure, which can have dramatic effects on demand (and thus supply) of equipment in the target sector.

System prices for off-grid applications tend to be greater than those for grid-connected applications, as the latter do not require batteries and associated equipment. In addition, for off-grid applications, provision is usually made in the system price for a programme of battery replacement approximately every five years.

Systems prices in the off-grid sector up to 1 kW varied from 7 to 20 USD/W, whereas a range of 8 to 24 USD/W was reported for systems larger than 1 kW. This large range of reported costs is likely to be a function of the project specific factors.

The installed cost of grid-connected systems also varied widely in price. The lowest reported were just

under 5 USD/W for systems installed under the Danish Sol-300 programme, and 4.5 USD/W in the Sacramento District Pioneer programme in the USA. The second phase of the City of the Sun project in the Netherlands has secured a turnkey contract that will deliver 700 kW of systems at 4 USD/W during 2001. The maximum reported was 14 USD for specific installations.

Figure 7 shows that, whilst there appears to be a continued downward trend in system prices over time, in more recent years this has slowed and now shows slight increases in some markets - probably due to specific cases of high demand in Japan and Germany.

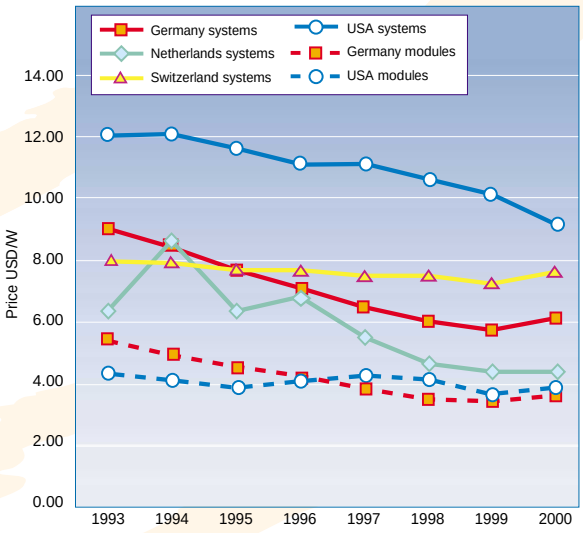

Figure 7 - PV module and system price trends in selected reporting countries

3.4 Employment

The wide scale implementation of government programmes to support PV development has led to the creation of many direct and indirect labour places. In the reporting countries it is estimated that this may account for just over 21 000 labour places in R&D, manufacturing and direct support services such as installation and maintenance. In those countries able to quantify the number, some 14 % worked in R&D, 42 % in manufacturing and 45 % in support services. However there is evidence that as the commercial sector takes up the challenge to service implementation programmes the proportion of those working in each of these roles changes significantly due to dramatic increases in the number of personnel working in this sector.

4 Framework for Deployment

Local, national and international policies and the perception of the general public and utilities govern the rate of deployment of PV systems. The availability of suitable and acceptable standards and codes is also a major factor.

4.1 New initiatives in photovoltaic power systems

Whilst increasing emphasis is being placed on market stimulation measures, research and development initiatives still attracted much interest from funding agencies. Demonstration programmes play a diminishing role. Table 6 highlights the key initiatives reported in the participating countries during 2000.

In general, the wide range of fiscal instruments being used to support or promote PV include: reduced interest rates, tax credits, accelerated depreciation, government or regional grants, preferential tariffs and 'green electricity' schemes. The prevalence of green electricity schemes in the reporting countries demonstrates that a significant, and growing, number of customers are concerned about the environment and prepared to pay more for electricity generated from environmentally-benign sources. Public opinion appears to be generally supportive of PV, although lack of awareness and access to information continues to be a barrier in some countries.

Utilities are also increasingly supportive of PV. Many now offer 'net metering', where the consumer only pays for the difference between the electricity generated by their PV system and the electricity purchased from the utility grid, and some are investing in PV either as part of corporate policy or to avoid the costs of grid extension in remote areas. The value of other network benefits attributed to PV does not, though, appear to be recognised. A common trend is the deregulation and privatisation of the primary electricity generation and supply businesses of many participating countries and this appears not to be generally positive for the higher cost generation provided by PV. As yet, there are only a few examples of where such privatised and deregulated industries are capable of recognising the 'Added Value' that PV technologies can provide.

Table 6 - New initiatives in the reporting countries

Country	Promotional initiatives	Utility and public perceptions	Major new initiatives and planned developments
AUS	The introduction of a Goods and Services Tax in Australia in 2000 removed the sales tax exemptions previously available for solar products. This has had the adverse effect of increasing the cost differential between fossil fuel and PV options, although the PV Rebate Programme was intended to provide compensation for this in the short-term. Some PV installation companies offer finance packages, through standard finance channels, for their systems.	Despite years of involvement with PV implementations at different levels, the utility perception is that PV is still too costly for central generation, while the advantages of distributed generation are yet to be fully acknowledged. Few investigations are underway into the use or value of PV for peak load reduction or grid support. Access to the main electricity distribution networks continues to be difficult for small, distributed generation systems. Procedures are complex, non-uniform, slow and costly. Although there is an increasing public awareness of greenhouse gas issues and a high interest in solar options, PV is still considered to be a future technology, or one suited only to off-grid use. Few retail outlets exist in high population centres and most Australians would not have ready access to information, products or installers.	A Government funded Renewable Remote Power Generation Programme will commence in 2001, providing 50% rebates, up to a maximum of 68 000 USD, for the renewable energy components of Remote Area Power Systems, with 144 MUSD having been allocated to the programme over 4 years. Another key initiative is the Mandatory Renewable Energy Target (MRET), which from 2001 will require electricity retailers and large users to supply a portion of their electricity from renewable energy sources. Although the target is not expected to have a significant benefit for PV, at least in the short term, it may serve to reduce some of the institutional barriers still facing small-scale distributed generation systems. System Manufacturers continue to show confidence with Pacific Solar releasing its Australian version of a unique modular rooftop solar PV system, BP Solar announcing major expansion plans and Sustainable Technologies International beginning production of its unique Titania dye sensitised solar cells.
CAN	Accelerated depreciation for the cost of PV systems greater than 3 kW resulting in Sales Tax reduction.	PV is attractive to the public for vacation cottages/cabins and recreational vehicles but the general perception is still that PV is too expensive. Year 2000 fears brought increased interest and activity.	As part of its strategy for the electricity sector, in its Action Plan 2000 for Climate Change, the Government announced measures to promote the use of emerging renewable energy sources. To implement this it allocated 0.8 MUSD to promote on-site generation at Government facilities using PV and wind systems, and 0.3 MUSD to address interconnection issues of small distributed power sources. Moreover, the Government, in collaboration with the Canadian Solar Industries Association and the Solar Energy Society of Canada, is planning a marketing and promotional initiative to raise awareness of PV in parks and to the general public.
CHE	Although the possibility of the liberalisation of the electricity market will lead to an increase in the price differential between PV and conventionally generated electricity, it is likely to open opportunities for the direct marketing of 'green power'. Additionally, legislation requires that low power sales are not to be subject to use of system charges for a period of ten years. The responsibility for the funding for promotional activities has now moved to a regional level.	Utilities have made efforts to establish new labelling schemes for solar and other "green" sources of electricity. These include a basic level (for existing hydro schemes etc) and a more stringent label for new renewables, such as photovoltaics. New "green electricity" offers are now being made by the utilities, which estimate a 20 % market share for their (more expensive) "green-labelled" power.	Following the rejection by referendum on a non-renewable energy levy to fund increased promotion of new renewables, the promotion of PV systems will now have to organised by private initiatives and will become increasingly a question of how "green" electricity can assert itself in a free market.
DNK	There has still to be a significant take up of the 36 % subsidy for PV applications in the commercial sector, which is funded by the CO_2 tax on electricity. Net metering for privately owned PV systems was established in mid 1998 for a trial period of 4 years, and is now likely to be extended. A 1 000 rooftop programme is under preparation and is expected to be launched in 2001.	Grid-connected PV applications are seen as the largest potential in Denmark, in particular building integrated applications on single family houses and apartment buildings. The public interest for building integrated PV is increasing, and most efforts are focussed on developing and demonstrating PV in the context of existing buildings.	The Sol-300 roof top programme was completed in 2000. The Public Service Obligation (PSO) is still under development but the political attitude is positive. As with many other countries the deregulation of the electricity supply industry continues with currently unclear long-term impacts on PV development.

Country	Promotional initiatives	Utility and public perceptions	Major new initiatives and planned developments
DEU	The implementation of Law for the Priority of Renewable Energies (REL) in April 2000 dramatically changed the rate of installation of grid-connected systems. The increase in applications was particularly marked in those Federal States that previously had had no PV support measures. It is currently possible to combine tariffs given under the REL with low interest loans provided under the 100 000 Roofs Solar Power Programme. Although following a dramatic increase in applications in early 2000, modified conditions have now been introduced.	Public opinion concerning renewable energy remains very positive. By the end of 2000 more than 50 suppliers were offering green power, compared to about 10 suppliers by the end of 1998. The unprecedented interest in the REL indicates a high level of public awareness and ability to participate in PV programmes.	Attention for the next few years will centre on the further development of applications in the framework of the 100 000 Roofs Programme and the REL. The government authorities are keen to effectively balance the supply and demand in PV products in the long term and provide stability to the market. This will be essential to avoid the excessive price rises seen in April/May 2000 system suppliers were limited. The future of PV generated power will be dependent on the success of the growing number of green power suppliers and other professional investors and how these can offer supplies successfully in the increasingly liberalised European power market.
FIN	Investment subsidies are granted for PV installations up to a maximum of 30 %. This applies only to companies and other legal entities, not individual householders. However, the possibility of expanding this scheme to cover private homes is being investigated.	'Green electricity' has been introduced to the electricity markets and utilities are increasingly interested in demonstrating building integrated PV systems as part of their environmentally friendly image. This increase in activity has also raised the public profile of PV. Interest has been shown to an ESCO type financing approach for PV installations to private homes.	The Government's Action Plan for Renewable Energy Sources was launched in 1999 and sets a target of 40 MW of installed capacity by 2010. In April 2000 a national solar energy day was organised and was accompanied by a new Finnish language publication on solar energy.
FRA	No new support initiatives have been launched during 2000, although support of up to 95 % of the cost of an off-grid domestic PV system is provided in conjunction with the FACE fund. Research and development efforts continues apace with the securing of a PV budget at ADEME and the increased interest of the Atomic Energy Commissariat (CEA) in renewable energy research.	EDF (the main electricity utility) and ADEME continue to promote the use of PV (and wind) for isolated houses, where grid extension is a more expensive option, through the FACE programme.	A new demonstration programme for grid-connected building integrated systems was initiated in 2000, with the aim is to install 500 kW in the next 3 years with a targeted installation cost of 5 USD/W. A new four year research and technical development programme aims to reduce production costs of PV cells and other system components in many application types.
GBR	Sales Tax on professional installations of PV systems has been reduced from 17.5% to 5 % (the minimum permissible). However, the reduced rate does not extend to householder installations, which is seen by some as a deterrent to more widespread deployment of small-scale systems and particularly 'AC' modules. A major utility company (TXU), under an agreement with the environmental group Greenpeace, is offering net metering of up to 1 000 residential PV systems. In the UK's deregulated market, the scheme is accessible to PV owners throughout the country.	The utility perception of PV is improving with most grid connection issues now resolved. However, problems and resistance are still evident in metering and supply aspects. The specific inclusion of PV in positive high-profile speeches by the Prime Minister and the Energy and Environment Ministers have helped to stimulate public interest and confidence and high visibility projects such as BP's Sunflower initiative likewise have served to improve public awareness.	A Domestic Field Trial is well underway, and is expected to see over 220 kW of PV installed in 2001/2002. The Government is to support a large-scale BIPV Field Trial with a budget of 4.2 MUSD over three years. This aims to provide a capital contribution for 12 to 15 large, high-profile and innovative non-domestic installations and the first projects contracts are expected to be let in 2001. A Climate Change Levy (tax) on business use of energy was introduced on 1st April 2001, from which renewable energy is exempt. An Obligation on electricity suppliers to supply a proportion (up to 10 % in 2010) of their supply from renewables will be introduced in 2001. The obligation should encourage development of near cost-effective renewable energy schemes, but is unlikely to promote photovoltaic generation capacity in the near to medium term.

Country	Promotional initiatives	Utility and public perceptions	Major new initiatives and planned developments
ISR	The Government provides support for PV grid-connected demonstration projects but the support is conditional on bringing the proposed project to a state of being 'cost effective'. The potential for growth in the PV market in the near future will be consumer pushed, rather than pulled by any national policy.	Public perception of PV is increasingly positive as a result of greater awareness of environmental issues in general. However, the high cost of installed systems (10 - 20 USD/W) and indirectly subsidised grid supplied electricity limits potential. The most significant projects still involve the supply of electricity to remote installations and dwellings.	The Yeruham - Solar City Initiative has seen some progress in approvals of various stages of this program.
ITA	In order to promote all renewable energy sources the Government has introduced measures to obligate the supply of 2 % of production from renewable sources and to give priority to the use of renewable energy in remote grids. A standard contract for the supply of PV electricity to the grid has been issued.	The utilities have demonstrated their support for the national roof-top programme by co-operating with ENEA to address technical issues relating to grid connection and some utilities are starting their own demonstration programmes. There is also widespread interest from the general public. In particular, a wide interest has been shown in the nation-wide rooftop programme.	The 10 000 roof top programme has been delayed further but is expected to start in 2001. The target capacity is 50 MW.
JPN	There are two key taxation measures available to support installations: property tax relief and tax credits based on PV investments. The former stipulates that the taxable amount of fixed property for individuals and private companies should be reduced to 17 % for three years. The latter stipulates that individuals and private companies can choose either tax credit of 7 % of acquisition value of PV systems or 30 % depreciation of acquisition value for the first year.	Net metering has been available since 1992 and several utilities have established a subsidy to support R&D on PV systems and a subsidies of half the cost of residential PV installations. Public support for PV is high and still growing and this is evident in the high rate of applications for the Residential PV System Dissemination Programme in 2000 (over 25 000).	The existing demonstration and fields-test programmes continue to make steady progress towards target of 5 000MW of installed PV capacity by 2010. New initiatives include an extension of the PV Dissemination programme to 2002, a law encouraging the purchase of green electricity by government agencies, and a 'Green Power Fund' has been launched by utility interests.
KOR	Whilst there have been no new promotional initiatives, the Government are revising regulations to enable a power buy-back schemes. Also the Government has launched an energy policy plan to enhance technology development and accelerate dissemination activities.	KEPCO, the monopoly utility company, continues to have an interest in PV, through its direct involvement in the construction of PV plant in remote islands and research activities in grid-connected PV. Public perceptions remain low.	The comprehensive energy plan announced in December 2000 should lead to the enhancement of technology development and accelerate dissemination activities in 2001.
MEX	Promotional activities are generally made as part of wider poverty alleviation or agricultural programmes. These are increasingly carried out at a state or local government level and have seen over 60,000 systems installed in more than 2500 communities. Commercial interests drive the non-domestic sector.	Utilities are only just becoming involved with the issue of the grid connection as practically all installations to date have been off-grid.	A key new project to explore the benefits of grid- connected distributed PV to reduce the peak electrical demand in regions with very high (over 45 ^{0}C) summer temperatures was launched in 2000.
NLD	From January 2001 onwards PV is part of Energy Premium Regulation (EPR), which is a regulation to stimulate energy saving measures and renewable energy options in dwellings. House owners who install a PV system are entitled to obtain a premium 3 USD/W. When the installation is the result of 'Energy Performance Advice' (EPA) the premium is increased by 25% to 3.8 USD/W). These new regulations open up a large new market segment for PV systems in existing buildings.	Electricity companies are involved in many PV-projects, because the vast majority of the projects consists of grid-connected applications. In many cases the ownership of the PV-systems stays with the electricity company, at least for several years. In these cases, PV is generally placed as part of a green power contract. With the liberalisation of the green power market (due July 2001) PV is becoming more and more a marketing tool to sell green power. Public perceptions and knowledge continue to increase.	Two new major projects will contribute significantly: the "Floriade" (at Aalsmeer 2 300 kW), and the next phase of "The City of the Sun" (at Vroonermeer, 700 kW). Many other large initiatives are in preparation, for instance at building co-operatives, which can apply for the EPR (being house-owners). Furthermore it is expected that the new RE programme in combination with the EPR for house-owners will lead to improvement of the supply chain for PV systems, which in turn will increase the market volume.

Country	Promotional initiatives	Utility and public perceptions	Major new initiatives and planned developments
NOR	No new initiatives have been reported	Growing interest from utilities to include PV in future programmes. Public support is widespread, but financial support is limited to component development.	The political and administrative authorities are discussing the introduction of new pollution taxes. However, direct impacts on PV dissemination will be limited.
SWE	There are no promotion initiatives or general subsidies for PV systems. However, in the current pre-commercial state of PV, new installations of significant size would most likely be considered as a demonstration system and may receive support from governmental funds.	The general view of PV as a long-term sustainable renewable energy technology is positive from the government, public and utility viewpoint.	Until recently the main activity in the national programme has been to identify and develop niche applications where PV will be cost effective as a stand-alone system. In the last couple of years the programme focus has shifted towards evaluating the application of PV in the built environment as a longer-term option.
USA	The key initiatives in the grid-connected distributed sector are: the Million Solar Roofs Initiative, the extended Sacramento Municipal Utility District (SMUD) Pioneer programme, the California PV Subsidy programme and the PV for Schools programme.	Concerns regarding Year 2000 compliance created a new image for grid-connected PV and led to a surge of sales of PV as a back up power system. The Utility Photovoltaic Group (UPVG) supports net metering as a mechanism for expanding PV markets. Widespread blackouts and supplier instability in California have raised public awareness of electricity supply issues and increased interest in sustainable supply solutions.	It is expected that the market will experience continued expansion following the California energy crisis. The SMUD Pioneer II project and the California photovoltaic subsidy market will be indicators of public interest in reduced-cost photovoltaic grid-connected systems, with the storage and inverter to provide a key-load "Uninterruptable Power Supply."

4.2 Indirect policy issues and their effect on the PV market

There are two key issues with an indirect, but important, influence on the PV market: namely, the Kyoto Protocol and deregulation of the electricity industry.

As a consequence of the international Framework Convention on Climate Change and the Kyoto Protocol, countries such as Denmark, Finland, Germany, Sweden and the UK have introduced taxes on forms of electricity generation that contribute to CO2 emissions. However, these taxes are too small to noticeably affect the economics of PV and in the USA some analysts have calculated that PV credits would be less than 0.01 USD/kWh if there were serious efforts to credit PV for mitigation of CO2. In some countries (examples are Denmark and the UK) the money raised from these 'carbon taxes' is used as an additional source of funds for the national renewable energy programme.

Perhaps more significantly, the Kyoto Protocol has stimulated a reappraisal of renewable energy policy and the setting of national targets for PV deployment. For example, in Japan a law concerning 'Promotion Measures to Arrest Global Warming' was passed and in Australia a range of new renewable energy programmes, including mandated purchase of renewable energy by electricity retailers, have been introduced as part of the national Greenhouse Strategy. Germany, Finland, France, Italy, Japan, and the Netherlands have all set targets for increasing PV deployment dramatically. In addition, the European Commission's proposed Directive on renewable energy support includes detailed targets which will influence PV deployment in its' member countries.

It appears increasingly unlikely that the USA will participate in the Kyoto Protocol as in its current form it is considered likely to harm the USA's economic growth potential. However, the USA accepts the need for action on excessive global warming and the other nations participating in Kyoto have indicated that they will continue to develop the Protocol. This common position has the potential to lead to a new round of policy negotiations in due course.

Since an increasing proportion of PV systems are grid-connected, restructuring of the electricity industry is an important factor. Deregulation has been achieved, or is currently underway, throughout many IEA counties according to many different models. The impact on PV is uncertain and varies widely. The increase in green power schemes and net metering is one outcome, as many utilities are expanding customer services and choice in the face of increased competition.

Deregulation has also opened up access to the grid. Accompanied by simplified connection procedures and requirements, this has permitted a dramatic growth in all types of distributed generation. However, market-led schemes promote the cheapest option and so do not necessarily lead to more PV installations. For example, in Australia, PV accounts for less than 0.1 % of the total green power produced and the new electricity trading arrangements in the UK will replace existing guaranteed prices for renewable electricity with an obligation on suppliers to obtain a percentage of their supply from renewable sources. Electricity suppliers will therefore select the cheapest renewable technologies. Also, the primary aim of liberalisation in the electricity supply industry is to drive down costs to the consumer. Thus, as electricity prices fall, the price differential separating PV from conventional electricity generation will increase.

4.3 Standards and codes

The importance of standards and codes in promoting and enabling the continued development of markets for PV systems has long been recognised. In 1981, the International Electrotechnical Commission (IEC www.iec.ch) established a Technical Committee (TC82) to prepare international performance and safety standards for PV. The IEC TC82 has published 26 international standards. There are 21 countries participating in reviewing the work of TC82, as well as 11 countries that have observer status. Currently, IEC standards development under TC82 includes six active working groups: glossary, modules, systems, balance-of-system components, concentrators, and certification. A new draft standard to cover "PV module safety qualification - IEC 61730" has been circulated for comments to 32 countries in 2000. Also, a standard is being drafted for the "Electrical safety of static inverters and charge controllers for use in PV power systems- IEC62109" with the participation of five recognised safety testing organisations in the USA (UL), Canada (CSA), Netherlands (KEMA), Germany (TUV) and Japan (JET). A committee draft for the "Certification and accreditation program for PV components and systems" IEC62078 has been reviewed by the Conformity Assessment Board of the IEC in 2000. TC82 co-operates with TC64 on a project to extend the wiring regulation (IEC60364) to include PV installations. A joint co-ordinating group between TC82 photovoltaic, TC21 batteries and TC88 wind energy has been established to revise "Specifications for the use of renewable energies in rural decentralised electrification" prepared by the French National committee.

In 1997, the Global Approval Programme (PV GAP www.pvgap.org) set up parallel activities focusing primarily on quality issues for stand-alone systems in developing countries. PV GAP differs significantly from the IEC in that it is driven by reliability and quality concerns of donor programme and the World Bank. It aims to issue a 'Quality Seal' to approved companies to ensure consistent reliability of PV systems. Currently PV GAP has issued 8 'PV Recommended Specifications' dealing with practical design details, installation guidelines and testing procedures. PV GAP was also responsible for writing the PV Manufacturers Quality Control Training Manual and for conducting training events in India, South Africa and China. In addition, PV GAP and the IEC TC82 have collaborated to produce a draft standard "PV stand-alone systems - design qualification and type approval - IEC62124" that is being circulated for approval in participating IEC countries.

5 Summary of Trends

Whilst there is great diversity between the countries participating in the IEA Photovoltaic Power Systems Programme and although this survey does not capture the whole PV market it does provide an indication of global trends with the reporting countries accounting for an estimated 80 % to 90 % of world production capacity.

- The market for PV power applications continues to expand rapidly: between 1999 and 2000 the total installed capacity in the reporting countries grew by 37 %, reaching 712 MW. Of the 192 MW installed during 2000, 175 MW was installed in Japan, Germany and the USA alone and thus care must be taken when analysing results to recognise this bias.

- Between 1992 and 2000, the installed grid-connected PV increased from 29 % to 61 % of the total capacity in the reporting countries, up from 53 % in 1999. In the main this is due to large scale, government or utility supported programmes, especially in Japan and Germany, which focus on

PV in the urban or suburban environment. Off-grid applications account for over 90 % of the total installed capacity in Mexico, Norway, Finland, Canada, Sweden, Israel, France and Korea.

- The public perception of PV and the contribution it can make to sustainability objectives has become increasingly recognised during the year. With the approach of the Year 2000 and fears about computer stability (the Y2K 'bug'), security of supply became of great interest to the media and the general public. Some of these fears were realised in California, not however due to any 'bug', but due to regulatory system failure, as rolling blackouts swept across the State. High profile projects in Europe, (particularly in Germany and the Netherlands) and Australia have made every day familiarity with PV a possibility. The installation of demonstration PV systems in educational facilities is a common theme with at least half of the reporting countries promoting schemes in this area.

- The total budget allocated by government bodies to support the PV industry in the reporting countries has increased by 26 % in 2000. In common with previous years, over half of this total budget was for Japan although other countries, in particular Korea, Australia and the UK saw significant increases in their PV budgets. Per capita budget spend is greatest in Switzerland, at just over 2 USD/capita. A continuing trend is the increasing proportion of the budget spent on market initiatives, which now tend to exceed that spent on research and development.

- Between 1993 and 2000, annual module production rose almost five-fold - from 52 MW to 238 MW - and in the last year it rose by 42%. In Japan, production increased by 60 %, down from an increase of 67 % last year, whereas in the USA and Europe the increase was around 30 %. As a result an increasing proportion of world module production is centred on Japan, which now commands 57 % of the market. Many new companies are poised to enter full production in 2001 in Australia, the USA, and Europe. In addition, most current companies report that they are planning to enlarge existing production lines. Although production appears to remain well below capacity (61 %), it is believed that this reflects the rapid expansion of the industry leading, for example, to problems with immature supply chains.

- The vast majority of modules produced are still crystalline silicon with a reduction seen in the production of amorphous silicon products. A number of other technology types are in production at a pilot scale, and many novel cell types are expected to enter full production soon.

- Although system prices do still show a general downward trend, this is not accelerating. Indeed, in a number of countries slight increases in prices were reported, probably as a result of sudden high demand for components in particular target sectors following the introduction of a subsidy or support scheme. Grid-connected building integrated systems of between 1 - 3 kW typically cost between 6 and 12 USD/W to install although prices below 5 USD/W were reported in Denmark, The Netherlands, Germany and the USA. One interesting trend has been where utility companies have been involved in district-wide implementation programmes; their bulk purchasing power has managed to procure systems and installation services at a considerable discount.

- In general, electricity utilities are increasingly supportive of PV: many now offer net metering or preferential tariffs for PV and are actively involved in project development. Whilst deregulation in the electricity industry continues to have an impact on PV deployment by decreasing wholesale electricity prices, it has opened opportunities for utilities to offer competitive niche products and to provide a framework for industry regulators to formulate sustainability and social obligations.

Table 7 - Installed PV Power and module production in the reporting counties

Year	Cumulative installed power and percentage increase						Power installed during year	Module production in year
	Off-grid		Grid-connected		Total			
	MW	%	MW	%	MW	%	MW	MW
1992	78		32		110			
1993	95	21	42	32	136	24	26	52
1994	112	19	51	24	164	20	28	
1995	132	18	66	29	199	21	35	56
1996	157	19	87	32	245	23	46	
1997	187	19	127	45	314	28	69	100
1998	216	15	180	42	396	26	82	126
1999	244	13	276	54	520	31	124	169
2000	275	13	437	58	712	37	192	239

Annex A IEA-PVPS Task I Participants

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Annex B Exchange Rates

The table below lists the participating countries, corresponding ISO country and currency codes, and the exchange rates used to convert national currencies. Exchange rates represent the annual average of daily rates.

Country	ISO country code	Currency and ISO code	Exchange rate (1 USD=)
Australia	AUS	Dollar (AUD)	1.83
Austria	AUT	Schilling (ATS)	15.31
Canada	CAN	Dollar (CAD)	1.52
Denmark	DNK	Krone (DKK)	8.30
Finland	FIN	Markka (FIM)	6.62
France	FRA	Franc (FRF)	7.30
Germany	DEU	Mark (DEM)	2.18
Israel	ISR	New Israeli Shekel (NIS)	4.08
Italy	ITA	Lira (ITL)	2154.86
Japan	JPN	Yen (JPY)	112.16
Korea	KOR	Won (KRW)	1134.27
Mexico	MEX	Peso (MXP)	9.47
Netherlands	NLD	Guilder (NLG)	2.45
Norway	NOR	Krone (NOK)	9.06
Portugal	PRT	Escudo (PTE)	223.12
Spain	ESP	Peseta (ESP)	185.17
Sweden	SWE	Krona (SEK)	9.66
Switzerland	CHE	Franc (CHF)	1.68
United Kingdom	GBR	Sterling (GBP)	0.71
United States	USA	Dollar (USD)	1.00
European Union		Euro (EUR)	1.12