IEA INTERNATIONAL ENERGY AGENCY

TRENDS IN PHOTOVOLTAIC APPLICATIONS

in selected IEA countries between 1992 and 2001

PVPS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

Report IEA - PVPS T1 - 11 : 2002

TRENDS IN PHOTOVOLTAIC APPLICATIONS in selected IEA countries between 1992 and 2001

Contents

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 (PV) 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 centralized 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 PV 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.

"With this 7th issue of the International Survey Report (ISR) on trends in photovoltaic applications, IEA PVPS is happy to publish the survey of 10 consecutive years of photovoltaic market development. Photovoltaic products, applications and markets continue to expand rapidly all over the world, in parallel with a growing industrial basis. These reports have gradually focused on the most important facts and figures of photovoltaic markets and industry as well as different initiatives in IEA countries. The IEA-PVPS Programme is proud to systematically track the important trends in the deployment of this new and sustainable energy technology and hope that this report can contribute to objective information on the important trends and raise the awareness about the exciting developments in this area."

Stefan Nowak
Chairman IEA-PVPS Programme
July 2002

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

Many thanks to all Task 1 participants who supplied images for this report.

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

August 2002

PV roof-lights at the JPS - Presse and Vertriests GmbH buildings in Meckenheim, Germany

1 Introduction

1.1 Survey report scope and objective

As part of the PVPS programme, annual surveys of photovoltaic (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 technology, 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 seventh international survey. It provides an overview of PV power systems applications and markets in the reporting countries at the end of 2001 and analyses trends in the implementation of PV power systems between 1992 and 2001.

1.2 Survey method

Data for this publication were drawn from national survey reports[2], which were supplied by representatives from each of the participating countries. A list of the national representatives and their assistants is given at the end of this publication.

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 technical writer analysed the data provided in the national survey reports and subsequently prepared this report. Following review by the national representatives the report was approved by the IEA-PVPS Executive Committee.

1.3 Definitions, symbols and abbreviations

Standard ISO symbols and abbreviations are used throughout this report. The electrical generation capacity of PV cells or systems is given as watt peak (W). This is the peak power of a PV module or system under standard test conditions of 1 000 $W.m^{-2}$ irradiance, 25 °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. The currency used is the US Dollar (USD), and the exchange rates used for the conversion from national currencies are given at the end of the report.

PV modules at the Airdie Environmental Centre, Canada

[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 Portugal or Spain this year and so the most recent data were used where appropriate.

2 Implementation of Photovoltaic Systems

2.1 Applications for photovoltaics

There are four primary applications for PV power systems:

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 commercially competitive.

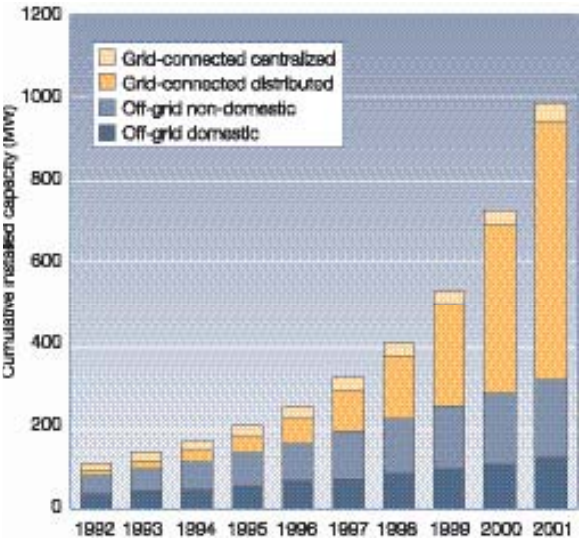
Grid-connected distributed PV systems are a relatively recent application where a PV system is installed to supply power to a building or other load that is also connected to the utility grid. These systems are increasingly integrated into the built environment and are likely in the future to become commonplace. They are used to supply electricity to dwellings, commercial and industrial buildings, and are typically between 0,4 kW and 100 kW in size. The systems usually feed electricity back into the utility grid when electricity generated exceeds the building loads. These systems offer a number of advantages: 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 generally energy storage is not required, a factor that also improves system efficiency and decreases the environmental impact.

Grid-connected centralized systems have been installed for two main purposes: as an alternative to centralized power generation from fossil fuels or nuclear energy, or for strengthening of the utility distribution grid. Utilities in a number of countries are interested in investigating the feasibility of these types of power plants. In past years 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.

2.2 Total photovoltaic power installed

A total of 982 MW of PV power had been installed in the reporting countries by the end of 2001. The increase in installed capacity between 1992 and 2001 is shown in Figure 1, broken down into the four primary applications for PV power systems. This represents a significant[3] 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

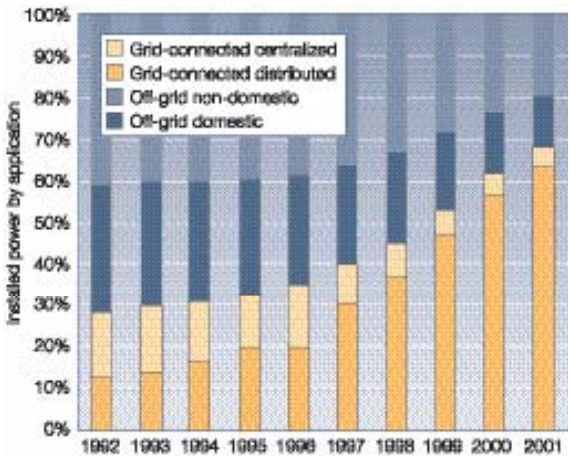


Between 1992 and 2001 the annual rate of growth of total installed capacity varied from year to year between 20 % in 1994 and 40 % in 2000. Between 2000 and 2001 the rate of increase was 35 %. It can be seen from Table 1 and Table 2 that the majority of this rise is due to the continued increases in Japan (122 MW) being joined by a significant increase in Germany (81 MW). Indeed it can be seen that of the 257 MW installed in 2001, 79 % was installed in Japan and Germany alone. This continued high rate of installation in Japan increases this country's lead in installed power per capita (3,6 W per capita) significantly above that of the second highest of Switzerland (2,4 W per capita).

Figure 2 indicates that until 1999 most PV systems installed were for off-grid applications. This is still true in the majority of the reporting countries and Figure 3 illustrates that in Canada, Finland, France, Israel, Mexico, Norway and Sweden over 90 % of the total installed capacity is off-grid. This encompasses a wide range of applications. In Finland, Norway and Sweden, the majority of off-grid PV systems are used for seasonal and recreational buildings and remote cabins. In France and Mexico, PV is used as a strategy for rural electrification. In Australia, Canada, Korea and Japan most off-grid systems are non-domestic and provide power for pumps, agriculture, traffic signals and telecommunications and also in Canada for extensive monitoring and controls in the oil and gas fields. 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 2001 this had reached 68 %, of which 93 % was for distributed systems. However, there was revised interest in grid-connected centralized PV, with over 8 MW installed in 2001, mainly in Germany and The Netherlands.

Figure 2 - Percentage of PV power in the reporting countries



Government or utility supported programmes in Japan, Germany, the USA and the Netherlands have driven the rapid rise in grid-connected distributed applications. These generally focus on PV in the urban environment. Significantly, the rates of increase in countries already with high levels of installed capacity have been high. Thus, increases over the year in the Netherlands (86 %) and Germany (78 %) imply step changes in the supply infrastructure to deliver high volumes of grid-connected systems.

[3] At the end of 1999, the worldwide installed PV capacity was estimated to be 931 MW [Photovoltaics in 2010: an Update and Observatory for the Millennium, EPIA for the EC (Altener XVII/4.1030/X/99-579), 2001]. In non-IEA countries this was predominately for off-grid applications.

Figure 3 - Installed power by application in the reporting countries in 2001

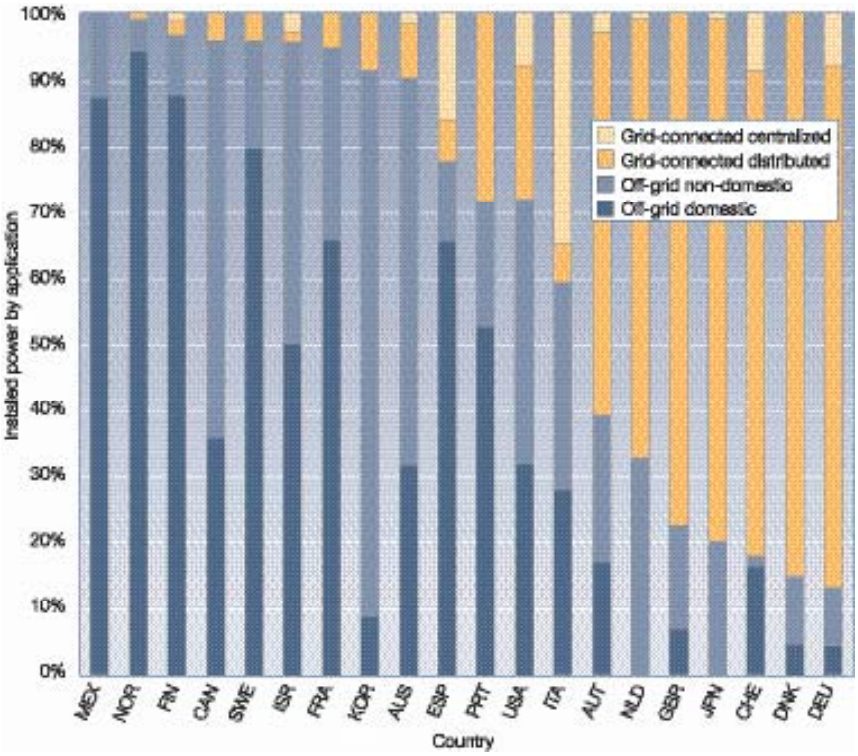


Table 1 - Cumulative installed PV power as of the end of 2001

Country	Off-grid domestic kW	Off-grid non-domestic kW	Grid-connected distributed kW	Grid-connected centralized kW	Total kW	Total installed per capita W/Capita	Power installed in 2001 kW
AUS	10 960	19 170	2 800	650	**33 580**	1,73	4 370
AUT		1 955	4 440	241	**6 636**	0,81	1 762
CAN	3 322	5 162	341	11	**8 836**	0,28	1 682
CHE	2 480	220	13 340	1 560	**17 600**	2,42	2 300
DNK	50	160	1 290		**1 500**	0,28	40
DEU	6 200	10 500	162 000	16 000	**194 700**	2,34	80 900
ESP[1]	5 900	1 100	600	1 480	**9 080**	0,23	
FIN	2 392	249	87	30	**2 758**	0,53	206
FRA	8 912	3 972	972		**13 856**	0,23	2 525
GBR	135	385	2 226		**2 746**	0,05	817
ISR	253	200	6	14	**473**	0,08	32
ITA	5 300	6 350	1 635	6 715	**20 000**	0,35	1 000
JPN	600	68 960	379 770	2 900	**452 230**	3,57	122 010
KOR	376	3 857	524		**4 757**	0,10	797
MEX	12 349	2 614	9		**14 972**	0,15	1 043
NLD		4 330	13 699	2 480	**20 509**	1,28	7 750
NOR	5 810	335	65		**6 210**	1,38	180
PRT[2]	484	176	268		**928**	0,09	
SWE	2 376	507	149		**3 032**	0,34	227
USA	50 500	64 700	40 600	12 000	**167 800**	0,60	29 000
Total	**118 399**	**194 902**	**624 821**	**44 081**	**982 203**	**1,01**	**256 641**

[1] *No data available for 2001or 2000. Installed PV power as at 31 December 1999*
[2] *No data available for 2001. Installed PV power as at 31 December 2000*

Table 2 - Cumulative installed PV power: historical perspective

	Cumulative installed PV power kW									
Country	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
AUS	7 300	8 900	10 700	12 700	15 700	18 700	22 520	25 320	29 210	33 580
AUT	573	839	1 133	1 361	1 739	2 208	2 931	3,672	4 874	6 636
CAN	960	1 240	1 510	1 860	2 560	3 380	4 470	5 826	7 154	8 836
CHE	4 710	5 775	6 692	7 483	8 392	9 724	11 500	13 400	15 300	17 600
DNK		85	100	140	245	422	505	1 070	1 460	1 500
DEU	5 619	8 900	12 440	17 790	27 890	41 890	53 900	69 500	113 800	194 700
ESP	3 950	4 649	5 660	6 547	6 933	7 100	8 000	9 080	9 080	9 080
FIN	914	1 034	1 156	1 288	1 511	2 042	2 170	2 302	2 552	2 758
FRA	1 751	2 051	2 437	2 940	4 392	6 118	7 631	9 121	11 331	13 856
GBR	173	266	338	368	423	589	690	1 131	1 929	2 746
ISR	100	120	150	180	210	265	308	401	441	473
ITA	8 480	12 080	14 090	15 795	16 008	16 709	17 680	18 480	19 000	20 000
JPN	19 000	24 270	31 240	43 380	59 640	91 300	133 400	208 600	330 220	452 230
KOR	1 471	1 631	1 681	1 769	2 113	2 475	2 982	3 459	3 960	4 757
MEX	5 400	7 100	8 820	9 220	10 020	11 022	12 022	12 922	13 929	14 972
NLD	1 270	1 641	1 963	2 400	3 257	4 036	6 480	9 195	12 759	20 509
NOR	3 800	4 100	4 400	4 650	4 900	5 150	5 404	5 726	6 030	6 210
PRT	169	219	258	336	424	527	648	844	928	928
SWE	800	1 040	1 337	1 620	1 849	2 127	2 370	2 584	2 805	3 032
USA	43 500	50 300	57 800	66 800	76 500	88 200	100 100	117 300	138 800	167 800
Total	**109 940**	**136 240**	**163 905**	**198 627**	**244 706**	**313 984**	**395 711**	**519 933**	**725 562**	**982 203**

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 new projects and programmes for 2001 reported below are for grid-connected systems.

Australia (AUS)

Growth in off-grid applications for PV is set to increase as the Renewable Remote Power Generation Programme commenced in 2001. Whilst each State has established varying criteria, in general the target groups are indigenous and other small communities, commercial and isolated domestic applications. Grants of up to 50 % are available for all renewable sources that replace diesel generators. This is a long term project, which may extend to 2010. The PV rebate programme, focusing on BIPV, installed another 1 100 systems in 2001 of which 78 % were also for off-grid systems.

PV lights in the Olympic Boulevard in Sydney, Australia

Austria (AUT)

Two very visible projects were completed in 2001, a PV noise barrier and a Solar Street. The noise barrier on

the A2 motorway at Gleisdorf stretches for 1,3 km and contains both amorphous and multicrystalline cells with an installed power of 101 kW. The project will monitor the performance and issues involved with operating PV systems in conditions exposed to dirt and impact damage. Also at Gleisdorf, an exhibition item called the "Street of Solar Energy" helped to illustrate the potential of PV systems to the 200 000 visitors to the event.

Canada (CAN)
Demonstration projects focused on BIPV systems aimed to demonstrate both retrofit and new build experience for designers and contractors. Projects include Canada's first PV curtain wall, at the British Colombia Ministry of Health, the first phase of a 140 kW system on the CN Tower in Toronto at a height of 400 m, the 40 kW Niigon Technology Centre sustainable development showcase, and two demonstration building-mounted PV systems funded by utility companies. Following a downturn in 2000, the off-grid domestic market grew strongly (43 %) despite no support or subsidy programme.

Denmark (DNK)
In 2001 the Government approved the SOL 1 000 programme, designed to build on the earlier success of the SOL 300 projects, and within a few weeks more than 3 000 households registered for the programme. This programme, aimed at single-family dwellings, is envisaged as the last "demonstration" project and standard subsidies are intended to follow in due course. A PV support programme for the commercial sector, providing a subsidy of up to 36 % of the total cost, has had a limited impact due to a limited uptake.

Finland (FIN)
Ekoviikki, a new suburb of Helsinki, is a unique demonstration project of ecological and sustainable housing. It is intended that this area will include up to 35 kW, of which at least 24 kW will be BIPV systems integrated into balcony structures.

France (FRA)
The emphasis in France continues to be for off-grid systems as part of a rural area electrification strategy, with the rate of installation of around 1,5 MW per year. The successful 'FACE' programme continues and has to date delivered over 1,1 MW of capacity in continental France. In the overseas Départements, tax exemptions and direct grants delivered just under 1 MW in 2001. Of new installed capacity, around 300 kW per year is grid-connected. A new rate based subsidy scheme for grid-connected generation is in preparation that will aim to deliver 20 MW of BIPV systems in 5 years.

Germany (DEU)
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 systems, with 72 MW of distributed systems and 6 MW of centralized systems installed in 2001. The average size of PV plant is steadily growing and provides an illustration of the financial attractiveness of PV plant under these measures. Two commercial centralized grid-connected projects have been started which have individuals as share holders. The first is a ground mounted 1,6 MW plant at Hohenfels-Markstetten in Bavaria and the second is the first phase of a 5 MW roof mounted plant at Relzow, in Mecklenburg-Vorpommern. The more modest 300 Parishes for Solar Energy aims to develop experience of distributed BIPV systems installed (791 kW) in historic buildings and the Sun at School programme continues with 310 kW installed in 2001.

Israel (ISR)
Nearly all of the applications in Israel are off-grid remote electrification systems. Most installations are made on an economic basis, PV being the most economically viable alternative (because of distance from the electric grid). A range of advanced research activities continues at universities and research institutes, funded mainly by the Ministry of National Infrastructures. The Ministry of the Environment is promoting PV through information dissemination activities. The Israel Electric Corporation is to invest 1 million USD in a 30-home grid-connected project in the Arava Valley, north of the resort city of Eilat, to investigate grid-connection and net-metering issues.

Italy (ITA)
With the imminent arrival of the major roof-top programme, projects during 2001 have been limited to a number initiated by ENEA (Italian Agency for New Technology, Energy and Environment). These 18 projects (totalling 50 kW) are designed to assess the architectural, performance and technical details of the solutions that will be installed under the roof-top programme which commences in 2002.

Japan (JPN)
Japan continues to make progress in implementing significant PV capacity through a range of research demonstration and market measures that provide targeted support in a number of sectors. Most of these measures provide a direct subsidy towards the installation costs of the equipment. Whilst the majority (over 80 %) of systems are installed in domestic installations of between 3 – 5 kW, interest in institutional, commercial and industrial applications is growing. PV systems on public facilities accounted for 5 % of installed systems and were typically in the range 10 – 50 kW, whilst commercial and industrial applications tend to be larger (10 – 100 kW) and account for another 5 % of installations. The unsupported commercial off-grid market (telecommunications, remote monitoring etc.) is also thriving.

The 630kW Solar Ark in Gitu, Japan

Korea (KOR)
The government continues to support the demonstration and field tests of various PV applications and has made efforts to encourage local authorities to implement their own demonstrations projects under the Local Energy Programme. The largest of these is a 107 kW system at the International Cave Exposition site in Samcheok, Gangwon Province. 2001 also saw the first residential roof-top system in Korea.

Mexico (MEX)
The majority of PV projects are directed at the 5 % of Mexicans in rural regions without grid-connected electricity. These projects have as their key aims poverty alleviation and agricultural development. Actions carried out since 1993 with the assistance of USAID and USDOE for the electrification of farms with PV have in 2001 concentrated on training installers and suppliers. The PV roof project aimed at reducing peak electrical loads in specific regions continued with most activities related to evaluation of the lead projects.

The Netherlands (NLD)
Innovative large scale and domestic scale projects have commenced in 2001. The world's largest centralized PV plant is the 2,3 MW BIPV system on a roof at the Floriade Exhibition Centre. Cooperative working between three city councils (Heerhugowaard, Alkmaar, Langedijk) and NOVEM has launched a 5 MW project to install PV systems on new-build houses and recreational facilities.

Norway (NOR)
Only one new demonstration project was completed in Norway in 2001, the installation of 16 kW on a headquarters building in Stavanger as BIPV to demonstrate grid-connected PV power. Other projects, including a series of European Commission demonstration projects called "PV Nord", were under preparation and will commence in 2002.

Sweden (SWE)
Seven main demonstration projects are reported as being commissioned in 2001, mainly in educational facilities. The largest of these, at Almedalens Library in Gotland (5 kW) and at the Harmonihuset in Malmö (8 kW) also provide a level of solar shading. Building companies are increasingly expressing interest in the need for training in PV system installation and maintenance.

Switzerland (CHE)
In 2001, a total of 45 pilot and demonstration projects were active, of which 11 were newly started. The majority of the newly started projects were concerned with building integration, especially in roofs. Other innovative projects include a PV passenger vessel on the lake at Zurich and a 17 kW installation at St. Moritz that utilized CIS technology. Multifunctional projects (PV / shading; PV / sound barriers) continue to be a feature.

United Kingdom (GBR)
Four developments totalling 69 kW were commissioned under the first round of the Domestic Field Trial (DFT) in 2001. In preparation for the major demonstration project launched in 2002, a second

round of the DFT field trials and a new field trial focussing on large-scale public buildings commenced in 2001 to evaluate the design and practical implementation aspects of the installations. In the Beddington Zero Energy Development (BedZED) PV provides charging points for 40 electric vehicles in this carbon neutral development of 80 houses and workspaces. A 16 kW array on “Big Brother House” – a reality TV show – brought PV promotion to an audience of many millions.

United States of America (USA)

The US PV programme made significant progress during 2001 with continuing and new projects in California. The State’s PV “buy down” programme resulted in the installation of 600 grid-connected residential systems and nearly 1 MW of commercial grid-connected capacity. The Sacramento Municipal Utility District (SMUD) launched its Pioneer II programme offering subsidized systems to mainly commercial customers. The PVUSA utility scale procurement programme by the Department of Energy concluded in 2001, having assisted, by direct subsidy, the installation of 9 MW of systems.

PV parking shelters in California, USA

Table 3 - Public budget for R&D, demonstration and market stimulation in 2001

	Annual budget Million USD			
Country	**R & D**	**Demonstration**	**Market stimulation**	**Total**
AUS	0,508	2,183	6,245	8,936
AUT	0,554			0,554
CAN	1,241	0,305	0,403	1,950
CHE	9,127	1,240	3,549	13,916
DNK	0,629	0,572		1,201
DEU	26,725	5,476	29,646	61,846
ESP				
FIN	0,520			0,520
FRA	8,346		7,409	15,755
GBR	4,706			4,706
ISR	0,225			0,225
ITA	5,536		34,321	39,857
JPN	50,964	16,507	188,389	255,860
KOR	1,768	4,507		6,274
MEX	0,726			0,726
NLD	2,983	0,081	5,950	9,015
NOR	1,125			1,125
PRT				
SWE	1,533			1,533
USA	35,000		84,600	119,600

Note: The costs of obligations placed on utilities are not included in the above table as these are generally passed to all electricity consumers

2.4 Public budgets for market stimulation, R&D and demonstration

The rapid growth in the rate of installation of PV capacity has been supported by significant National, Federal and State budgets for market stimulation, research and development, and demonstration. Table 3 gives these budgets for 2001 for a selection of reporting countries. It should be noted that the boundaries of what constitutes 'research', 'development', 'demonstration' and 'market stimulation measures' often vary from country to country and are thus not always comparable. Where possible, estimates of the breakdown between these elements have been made.

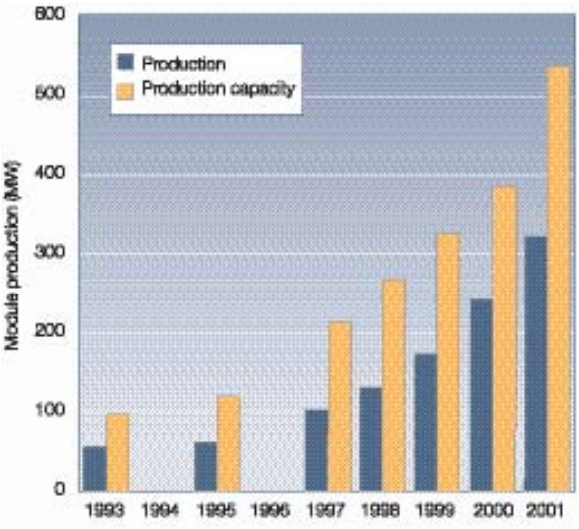
It is clear that the budget for the demonstration of technologies remains a small proportion of the total spent in this area, this year about 6 % of the total reported. The greatest proportion of effort is directed towards market stimulation measures that account for 67 % of budget spending. It is interesting to note that while not all countries report spending on demonstration projects or market stimulation measures, consistent programmes for R & D are common.

3 The PV Industry

3.1 Photovoltaic cell and module production

The total PV cell production reported in 2001 was in the order of 345 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 cells produced worldwide. This figure is a significant increase (42 %) on the cell production during 2000. Module production grew strongly again during 2001 to total 319 MW as illustrated in Figure 4. This figure also indicates an apparent low level of utilisation (60 %) of the reported 532 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.

Figure 4 - PV module production and module production capacity between 1993 and 2001



The increase in module production can be attributed to 34 % rise in production in Japan being complemented by increases of 32 % in the USA and 36 % in Europe. It can be seen from Table 4 that, as in 2000, over 57 % of all the modules produced in 2001 were from Japan.

Table 4 - PV cell and module production in 2001 by world region

	Cell production	Cell production capacity	Module production				Module production capacity
			Crystalline	Amorphous	Other/Both	Total	
Japan	170	236	157	14	11	182	293
USA	104	150	55	11	8	74	117
Europe	62	98	16	11	29	56	111
Rest	10	11	7			7	11
TOTAL	**345**	**494**	**235**	**36**	**48**	**319**	**532**

Module production remains based, predominantly, on crystalline silicon technologies, of which approximately 60 % is multicrystalline and 40 % is single crystalline. Amorphous silicon products have still to make a significant impact on the PV power market, although recent drops in amorphous silicon module production were reversed in 2001 with a sharp rise of 59 %.

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.

The major manufacturers maintain extensive in-house research and development teams, and are actively promoting new products and new product formats to meet distinct market groups. Significant effort is also directed towards automating production facilities to decrease cost and increase quality. For details of these new products and new production facilities, reference should be made to the relevant National Survey Report on the PVPS Programme website (www.iea-pvps.org).

Table 5 - PV Product manufacturers in reporting countries

Country	Company	Technology type	Total production		Maximum production capacity	
			Cell MW per year	Module MW per year	Cell MW per year	Module MW per year
AUS	BP Solar	sc-Si	4	2,5	4	2,5
		mc-Si	6	3,7	6	3,7
	STI	Titania Dye	0,01	0,01	0,5	0,5
CAN	ICP Global	sc-Si, mc-Si				2
CHE	Star Unity	sc-Si		0,02		0,1
	Solterra SA	sc-Si				
	SES	sc-Si				
	Swiss Sustainable Systems	sc-Si				1
	VHF Technologies	a-Si				0,1
DNK	Gaia Solar	mc-Si,sc-Si		0,09		0,33
DEU	>30 companies	mc-Si, sc-Si, EFG, a-Si, CIS, CdTe	31,8	28,94	57	56,05
ESP	Atersa	sc-Si		1		1,5
(2000)	BP Solar Espana	sc-Si	4,4	4,6	4,4	10
	Isofoton	sc-Si	0,64	3,4	0,64	5
FRA	Photowatt International	mc-Si	13,6	5	14	7
	Free Energy Europe	a-Si		0,5		1
GBR	Intersolar	a-Si	1,6	1,6	3	3
ITA	Eurosolare	sc-Si	0,5	0,5	0,5	0,5
		mc-Si	4	4	4	4
	Helios Technology	sc-Si	2	2	2,5	2,5
JPN	Kyocera	mc-Si	55	54	60	60
	Sharp	sc-Si	10,89	10,89	94	94
		mc-Si	64,12	64,12		
		a-Si	0,01	0,01		
	Sanyo Electric	a-Si	4	4	5	5
		a-Si/sc-Si	10	10	28	28
	Canon	a-Si/micro-crystalline-Si	1,59		10	

Table 5 - continued

Country	Company	Technology type	Total production		Maximum production capacity	
			Cell MW per year	Module MW per year	Cell MW per year	Module MW per year
JPN	Showa Shell Sekiyo	sc-Si		0,6		2
	Mitsubishi Electric	mc-Si	14	14	16	16
	Kaneka	a-Si	8	8	20	20
	Matsushita Battery	CdS/CdTe,mc-Si	1,2	1,2		
	MSK	mc-Si		8		35
		sc-Si		5		25
	Matsushita Seiko	sc-Si	0,6	0,6	2	2
		mc-Si	0,1	0,1	1	1
	Asahi Glass	sc-Si/mc-Si		0,1		0,2
	Kobe Steel	mc-Si		0,1		1,2
	Fuji Pream	sc-Si		0,01		0,1
		mc-Si		0,02		
	Nisshin A & C	a-Si		1,3		3,6
KOR	LG Industrial System	sc-Si		0,35		0,5
	Samsung Electronics	mc-Si		0,35		0,5
	Haesung Solar	sc-Si		0,07		0,5
	Solar Tech	sc-Si, mc-Si		0,13		0,5
NLD	Shell Solar Energy AKZO Nobel Logic Electronics	mc-Si	3,4	3,4	3,5	7
NOR	ScanCell	mc-Si			8	
SWE	GPV	sc-Si, mc-Si				10
	Arctic Solar	mc-Si		0,85		1
	Sunpeak	mc-Si				1
USA	Shell Solar	sc-Si	38	30	40	40
		CIS	0,7	0,7	2,5	2
		Cd-Te	0,3	0,3	0,3	0,3
	BP Solar	mc-Si	17,7	15	24	24
		a-Si	7	7	9	9
	AstroPower	sc-Si	26	10	50	20
		Si film	1	1	2	2
	ASE Americas	EFG-Si	8	5	10	10
	United Solar Systems (USSC)	a-Si	3,8	3,8	5	5
	Evergreen Solar	String ribbon	0,4	0,4	4	4
	Other		0,8	0,5	3	1
TOTALS			**345,16**	**318,76**	**493,84**	**532,18**

Notes

sc-Si	*single crystal silicon*
mc-Si	*multicrystalline silicon*
EFG	*edge fed growth silicon*
a-Si	*amorphous silicon*
CIS	*copper indium diselenide*
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” at the end of this publication provides a brief technical description of these components.

The price of grid-connect inverters has shown continued reductions in 2001. Typical prices are between 450 to 750 USD per kVA capacity for inverters in the range of 1 to 10 kVA. Prices are generally lower for larger units. 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 in times of grid failure.

3.3 System prices

Prices for entire PV 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 price of the system will vary significantly depending on whether the system is retrofit or is integrated into a new building structure. Another factor that has been shown to have a significant effect on price is the presence of a market stimulation measure, which can have dramatic effects on demand (and thus supply) of equipment in the target sector. The cost and complexity of permits and controls on grid connection can also be a significant factor for smaller systems.

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 sometimes made in the system price for a programme of battery replacement approximately every seven years.

In 2001, systems prices in the off-grid sector up to 1 kW varied from 7 to 19 USD per watt - a very similar range was reported for systems larger than 1 kW.

This large range of reported prices is likely to be a function of the project specific factors.

The installed price of grid-connected systems also varied widely in 2001. The lowest reported were approximately 4,6 USD per watt for large scale (> 1 MW) systems installed in Germany, and 4,5 to 5,0 USD per watt in the USA.

Figure 5 shows that, whilst during 2000 there appears to have been a levelling of prices – probably due to specific cases of high demand – the overall trend remains at around 4 % reduction per annum. Note that this figure shows system price trends, and there are many local factors – an example may be grid-connection costs - that can influence the prices in various countries. It is interesting to note a convergence of prices, indicating that more worldwide trading of modules is levelling out product prices. Figure 5 also shows trends in module prices for some countries and it can be seen that these are generally 40 – 50 % of installed system costs.

Table 6 gives some indication of how the purchase prices of modules that are common in the country indicated have varied over the last four years. Table 7 provides a comparison of the price of typical applications delivered as complete projects.

Figure 5 – PV system price trends in some reporting countries

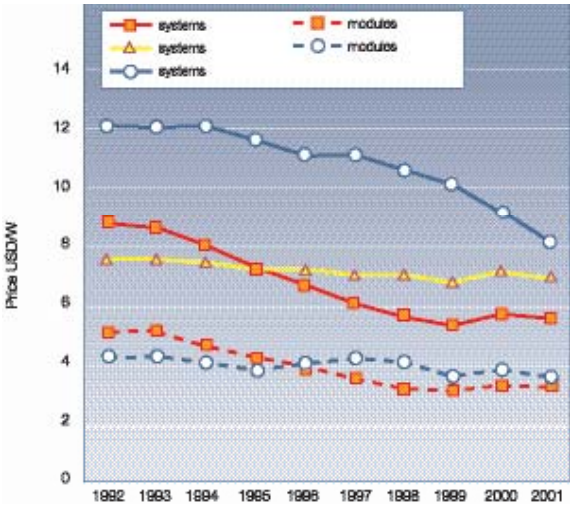


Table 6 - Module prices in selected countries

	Currency	Indicative module prices in national currency 1998	1999	2000	2001
AUS	AUD		8,0	8,0	8,0
CAN	CAD		11,1	10,7	9,4
DNK	DKR			40,0	40,0
DEU	EUR	3,7	3,6	3,8	3,8
FIN	EUR		9,3	9,0	8,0
GBR	GBP				3,5
ITA	EUR			4,1	4,3
JPN	JYP	670	600	548	484
KOR	KRW	9 200	7 500	7 100	7 200
NLD	EUR	5,0	4,8	4,7	4,7
USA	USD	4,0	3,5	3,8	3,5

Note: These prices are example module prices for applications in the country concerned and exclude sales taxation, delivery or installation

Table 7 - Installed system prices in selected countries

	Off-grid <1 kW USD per W	> 1kW USD per W	Grid-connected < 10 kW USD per W	>10 kW USD per W
AUS	11,7	9,4	7,1	6,3
AUT			6,8	6,2
CHE	11,3	9,0	7,0	6,1
DNK	9,2	20,0	6,9	10,9
DEU	7,0	7,8	5,5	4,7
FIN	13,2		6,8	6,8
FRA	12,8	19,6		
GBR	14,0	11,9	10,6	9,4
ITA	11,5	11,1	6,3	6,1
JPN			6,2	7,6
KOR	18,1	17,4	11,5	10,3
MEX	13,3			
NLD			5,6	5,3
NOR	10,7	10,7		
SWE	16,6		6,2	
USA	18,5	16,0	10,0	8,5

Note: These prices are indicative installed system prices and exclude sales taxation

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. Table 8 gives estimates of PV industry employment in some of the reporting countries. In those countries able to disaggregate the data, 10 % worked in R & D, 40 % in manufacturing (including company R & D) and 50 % in other roles that include installers, utility companies and government. In those counties with high growth rates of installed capacity, such as Germany and Japan, rapid growth in employment has occurred in those organisations concerned with the manufacture, supply and installation of systems.

Table 8 - PV industry employment in some countries

	R & D persons	Manufacturing persons	Other persons	Total persons
AUS	30	320	250	600
AUT				475
CAN	40	75	160	275
CHE	130	5	350	485
DNK	8	15	10	33
DEU	460	2 200	3 340	6 000
FIN	15	20	50	85
FRA	65	320	170	555
GBR	65	170	125	360
ITA	110	75	300	485
JPN	300	1 700	2 000	4 000
KOR	42	77	32	151
NLD	140	300	160	600
NOR	14	140	12	166
SWE	23	84	13	120

Note: R & D: Research and development (not including companies)
Manufacturing: of PV system components, including company R & D
Other: includes within utilities, installers, distributors, and government

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 public funding agencies. Demonstration programmes play a diminishing role. Table 9 highlights the key initiatives reported in the participating countries during 2001.

In general, the wide range of fiscal instruments being used to support or promote PV include: reduced interest rates on loans, 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 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, with a growing level of awareness and access to information reported in many countries.

Utilities are also increasingly supportive of PV. In countries where it is permitted, 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. Some utilities are investing in PV as part of corporate policy, to avoid the costs of grid extensions in remote areas, or to counter the effects of demand peaks in hot weather. The value of other network benefits attributed to PV does not, though, appear to be recognized. The disaggregation and privatisation of the primary electricity generation and supply businesses in many participating countries continues to gather pace. The lower bulk prices of electricity generation that result are not positive for the higher cost generation provided by PV. However, the market reforms may allow for easier grid access for small generators.

Table 9 - Initiatives and perceptions

	Promotional Initiatives	Utility and public perceptions
AUS	The off-grid PV market is set to expand rapidly, with the commencement of the substantial Renewable Remote Power Generation Programme, which generally offers a 50 % rebate on components used to replace diesel fuelled generators.	Although utilities are generally supportive of PV, few are active in installing any significant systems. The public have shown strong support for PV, demonstrated by the over subscription to the PV roof-top programme and the Renewable Remote Power Generation Programme. However, even with grants, the household costs of installing PV are still perceived as high.
AUT	Each state within Austria has implemented programmes that give varying support to PV. Some are very ambitious, with combinations of direct subsidy and preferential tariffs.	The liberalization of the electricity market in Austria has transformed the market for new renewables in the country, with an obligation on supply from new generation sources and the emergence of green electricity suppliers. Standardized energy supply patterns are available for small (<50 kW) generators and guarantee simple grid access for PV.
CAN	Within the framework to reduce greenhouse gas emissions, a number of programmes are delivering PV projects. These include innovation, community and infrastructure related activities.	Deregulation of the electricity industry in two provinces has lead to some product offerings for green electricity, however these have a limited impact as yet. Government regulations and utility attitudes strictly prohibit net-metering. Applications for grid connection are still considered on a case-by-case basis, however there is a concerted effort to reduce these barriers.
CHE	No new promotional initiatives have started during 2001, but the Swiss National Exhibition “Expo.02” includes a programme launched in April 2001 that promote renewable energy and energy efficiency.	Utility companies are continuing to make efforts to promote their “green” electricity offerings, which are estimated to account for 20 % of the market. The possibility that liberalization of the electricity market may depress wholesale market prices for electricity is partially offset by increased opportunities for “green electricity” marketing and exception of low voltage supply from energy transport costs for 10 years.
DNK	The launch of the SOL-1000 programme as a successor to the SOL-300 programme has been welcomed and intends to deliver 1000 roof-top installations within 4 years. Continued cost reductions and a trend towards smaller systems is expected.	The focus within utilities is for the interest in small, perhaps DIY, installations as a major new business area. The Public Service Obligation by utilities will be a force to promote funding for PV in a market dominated by the deregulation of utility activities. Public support and familiarity with PV is well established.
DEU	The existing German 100 000 Roofs Solar Power Programme in combination with the Renewable Energy Law has proved an extremely successful market instrument. With high demand, the 350 MW limit on the programme has now been lifted to 1 000 MW. A new agency, Deutsche Energie Agentur (dena) has been established to promote the export of renewable technologies.	The large number of green power utilities, investors and other professional institutions in the German PV market has lead to a high share of large (>1 MW) power plants in operation. High levels of market participants are driven by extremely strong consumer demand. Connection practicalities are routine.

Table 9 - continued

	Promotional Initiatives	Utility and public perceptions
FIN	The launch of the Finnish National Climate Strategy includes an Action Plan for Renewable Energy that will provide a significant emphasis on market issues for PV in the next year.	Green electricity products are offered mainly as a way of demonstration environmental credentials. The main public image of PV is for the electrification of summer cottages, although new BIPV projects and a number of school installations are raising the profile amongst other groups
FRA	The adoption of the EU's Directive on Renewable Energy by France raises the target for renewable energy generation to 21 % in 2010 and has increased the profile of renewables in France. Subsidies for SME's may be available under a scheme for the improvement of energy efficiency (PNA2E) and the price for purchase of PV electricity has been increased to 0,15 EUR/kWh (mainland) and 0,30 EUR/kWh for overseas Departments.	EDF, the electricity utility, has presented a strategic plan defining its strategy and this plan makes sustainable development central to its future development. The authority established to oversee deregulation of the electricity industry (CRE) will control the operation of the emerging market, and ensure that new entrants, including green electricity suppliers, have fair access.
GBR	Most promotional activities are being undertaken by private companies. These have been enhanced by the commencement of the field trials and the large scale demonstration programmes.	Policy announcements by senior political figures, backed by the commencement of support programmes have helped to raise the profile of all renewable energy technologies. Well funded campaigns by private companies including Solar Century, Intersolar and BP have brought PV to a wide audience for the first time.
ISR	Two new projects are planned by the Israel Electricity Corporation: A 100 MW centralized solar thermal power plant and a 30 home solar village. This latter project is designed to evaluate practical implementation issues.	The IEC (National Electricity Utility) has started a more active involvement in PV, mainly to investigate grid-connection and net metering issues as a result of pressure from the public, environmental NGOs and the Ministry of National Infrastructures.
ITA	The Italian Roof-Top programme started in 2001, with significant funds being provided to realize building integrated systems. The first part of the programme - directed towards public buildings - has been heavily oversubscribed and additional funds have been provided. The second sub programme aimed at individuals and private companies, aims to deliver 1 800 installations by the end of 2002	ENEL (the national electricity utility) have actively participated in overcoming technical and practical connection issues and has established a renewable energy trading company. The Roof-Top programme has sharply raised the profile of PV in line with increasing environmental awareness.
JPN	A new "Support Programme to Arrest Global Warming" was launched in 2001 to complement the many other programmes that continue in Japan. This scheme aims to support and promote the demonstration of organizational investments in new energy and energy efficient facilities.	Net metering has been a function of utility operation in Japan since 1992, and grid connection is routine. Utilities are generally supporters of PV, with over 5,6 MW installed as of the end of March 2001 on their own facilities. Public perception and acceptance of PV's role is strong.
KOR	No new promotional activities were started during 2001, but low interest rates are available for PV as part of a wider energy programme.	KEPCO, the monopoly utility company under restructuring, has maintained its interest in PV, particularly related to the electrification of remote island communities. A recent long term strategy for energy includes PV and wind in the medium to long term.

Table 9 - continued

Promotional Initiatives		Utility and public perceptions
MEX	The majority of activities are directed at providing electricity to the 5 % of Mexicans living in villages without grid connections. These projects meet poverty alleviation and agricultural development aims with minimum costs and environmental impacts.	Utilities have only become involved with grid-connection of PV in areas where roof-top systems have been used to reduce peak electrical demand in high summer.
NLD	PV became part of the Energy Premium Regulation (EPR) from January 2001, and this has stimulated a large new market segment in PV on existing as well as new build dwellings. However, PV inclusion in this programme has meant the end of the dedicated innovation PV programme PV NOZ - PV RD&D. The replacement programme concentrated on total of renewable energy generation, which made it difficult for PV to be competitive against other, larger scale, renewable energy generation options.	Utilities are currently involved in many grid-connected PV projects and the practicalities of connection are routine. Research has commenced on the effect that the high level of embedded PV generation in some areas may have on grid control. General knowledge of PV amongst the general public continues to increase steeply, with over half of those with domestic PV installed, already planning an expansion.
NOR	There are no specific new initiatives to report.	The key market for PV in Norway, the electrification of remote dwellings and holiday cottages, is beginning to stagnate, indicating a wide acceptance and familiarization with PV applications. Whilst there are a few grid connected demonstration projects, the utility and policy perception is that the country's other significant energy resources (natural gas, hydro, wind, & biomass) will dominate long term energy planning.
SWE	There continue to be no promotional activities or subsidies available for PV, unlike those available for other renewable energy sources such as biomass or wind. However, as the technology is seen as pre-commercial, a development of significant size would be a candidate for demonstration funds.	Whilst the utilities have sponsored some demonstration projects and other activities, the general view is that PV is not a technology suitable for Swedish climatic and market conditions. However, public perceptions reinforce the widely held view that PV will play a major role in power generation in the medium to long term.
USA	The Sacramento Municipal Utility District (SMUD) Pioneer programme has moved into Phase II, where subsidized grid-connected systems are sold to customers. California's Emerging Renewables Buydown Programme has stimulated 2,5 MW of PV by capital subsidy of up to 50 % of the installed system costs.	The energy crisis in 2000 in California continues to have repercussions throughout the USA. Whilst these problems were a function of a failed deregulation of the industry, along with increased world tension, they have heightened the general concern as to energy security, partly to the benefit of renewable energy but also to that of the oil, coal and nuclear industries.

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 market reform of the electricity industry.

As a consequence of the international Framework Convention on Climate Change and the Kyoto Protocol, countries such as Denmark, Germany, Sweden and the UK have introduced taxes on forms of electricity generation that contribute to CO_2 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 per kWh if there were serious efforts to credit PV for mitigation of CO_2. 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 Directive on renewable energy support includes detailed targets, which will influence PV deployment in the member countries.

Whilst the USA will not participate in the Kyoto Protocol as it is considered likely to harm the USA's economic growth potential, the USA accepts the need for action on excessive global warming. In addition, the issue of security of energy supply has been revisited in the USA and measures to support renewables, including PV, are likely to be a feature of a future energy policy that will also revitalize the domestic oil, coal and nuclear industries.

As noted in the previous section, reform of the electricity supply industry has been achieved, or is currently underway, throughout many IEA countries 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. Reform 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, the value of Renewable Energy Certificates traded to meet that country's MRET obligations is less than 5 % of the current typical cost (per MWh) of PV generated electricity. In the UK an obligation on suppliers to obtain a percentage of their supply from renewable sources will replace existing guaranteed (NFFO) prices for renewable electricity. Electricity suppliers will select the cheapest renewable technologies available. 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 may increase in the near term.

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 recognized. 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.

The range of the TC82's work is wide. Recently approved new work includes "Safety Guidelines for grid-connected PV systems mounted on buildings – IEC 62234", "Performance testing and energy rating of terrestrial PV systems – IEC 61853", "Electrical Safety of Static inverters and charge controllers for use in PV power systems – IEC 62109", and "Testing

procedure – Islanding prevention measures for power conditioners used in grid-connected PV power systems – IEC 62116".

Much of the drafting is undertaken in conjunction with the participation of five five recognized safety testing organisations in the USA (UL), Canada (CSA), Netherlands (KEMA), Germany (TUV) and Japan (JET). 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 decentralized electrification" prepared by the French National committee (IEC 62257).

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 programmes 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 eight 'PV Recommended Specifications' dealing with practical design details, installation guidelines and testing procedures.

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 over three quarters of world production capacity.

- The market for PV power applications continues to expand: between 2000 and 2001 the total installed capacity in the reporting countries grew by 35 %, reaching 982 MW. Of the 257 MW installed during 2001, 79 % was installed in Japan and Germany alone and care must be taken when analysing results to recognize this bias.

- Between 1992 and 2001, the proportion of grid-connected PV capacity increased from 29 % to 68 % of the total, up from 62 % in 2000. This is mainly due to large scale, government or utility supported programmes, especially in Japan, Germany and the USA, which focus on PV in the urban or suburban environment. Off-grid applications account for over 90 % of the total installed capacity in Canada, Finland, France, Israel, Mexico, Norway and Sweden.

- The public perception of PV and the contribution it can make to sustainability objectives has become increasingly recognized during the year. 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

Table 10 - Installed PV power and module production in the reporting countries

Year	Cumulative installed power and percentage increase						Power installed during year	Module production during year
	Off-grid		Grid-connected		Total			
	MW	%	MW	%	MW	%	MW	MW
1992	78		31		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	158	19	87	32	245	23	46	
1997	187	19	127	46	314	28	69	100
1998	216	15	180	42	396	26	82	126
1999	244	13	276	54	520	31	124	169
2000	277	14	449	63	726	40	206	238
2001	313	13	669	49	982	35	257	319

countries promoting schemes in this area. In the USA, security of supply issues have raised political interest in all domestic energy supplies, including PV.

- Whilst the trends in the total national budgets for R & D, demonstration and market stimulation measures are not reported this year, a continuing trend is the increasing proportion of the budget spent on market initiatives, which now tend to dominate government spending indicating a shift towards large scale implementation.

- Between 1993 and 2001, annual module production rose more than six-fold - from 52 MW to 319 MW. Currently 49 % of cell production and 57 % of module production in the reporting countries is centred on Japan. Most companies report that they are planning to enlarge existing production lines. Although production appears to remain well below capacity (at 60 %), 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 but production of thin film amorphous silicon products have seen a 59 % increase in 2001. A number of other technology types are in production at a pilot scale, and the first large scale projects using these technologies have been commissioned for evaluation.

- System prices have regained their general downward trend, which averages at around 4 % per annum. This follows the reporting of slight increases in prices in 2000, 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 per watt to install although prices below 5 USD per watt were reported in Denmark, Germany, the Netherlands, and the USA.

- 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 market reform 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.

IEA-PVPS Task 1

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Exchange rates

Table 11 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.

Table 11: exchange rates

Country	ISO country code	Currency and ISA code	Exchange rate (1USD=)
Australia	AUS	Dollar (AUD)	1,97
Austria	AUT	Euro (EUR)	1,17
Canada	CAN	Dollar (CAD)	1,54
Denmark	DNK	Krone (DKK)	8,74
Finland	FIN	Euro (EUR)	1,17
France	FRA	Euro (EUR)	1,17
Germany	DEU	Euro (EUR)	1,17
Israel	ISR	New Israeli Shekel (NIS)	4,20
Italy	ITA	Euro (EUR)	1,17
Japan	JPN	Yen (JPY)	124,80
Korea	KOR	Won (KRW)	1308,00
Mexico	MEX	Peso (MXP)	9,37
Netherlands	NDL	Euro (EUR)	1,17
Norway	NOR	Krone (NOK)	9,33
Portugal	PRT	Euro (EUR)	1,17
Spain	ESP	Euro (EUR)	1,17
Sweden	SWE	Krona (SEK)	10,83
Switzerland	CHE	Franc (CHF)	1,77
United Kingdom	GBR	Sterling (GBP)	0,71
United States	USA	Dollar (USD)	1,00

PV technology note

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

Cells and modules

At present, the vast majority of photovoltaic cells are made from silicon. In general, cells are classified as either **crystalline (monocrystalline** or **multicrystalline)** or **thin film**. Monocrystalline PV cells are manufactured using a single crystal growth method and have commercial efficiencies between 12 % and 15 %. Multicrystalline modules, usually manufactured from a melting and solidification process, are becoming increasingly popular as they are less expensive to produce but are marginally less efficient, with efficiencies between 11 % and 14 %. Thin film cells are constructed by depositing extremely thin layers of photovoltaic materials (typically silicon) onto a low cost backing such as glass, stainless steel or plastic. Module efficiencies for thin film products are currently around 7 % but are potentially cheaper to manufacture than crystalline cells. The disadvantage of low conversion efficiency is that larger areas of photovoltaic array are required. Other thin film materials are polycrystalline silicon, cadmium telluride (CdTe), and copper indium gallium diselenide (CIGS).

Further research and development is being carried out to improve the efficiency of all the basic types of cells with laboratory efficiencies for monocrystalline cells over 25 % and for thin film technologies over 13 % being achieved.

Modules are usually mounted in an aluminium frame and are typically rated between 10 W and 200 W, but several manufacturers now offer modules above 200 W. Crystalline silicon modules consist of individual cells connected together and encapsulated between a transparent front, usually glass, and a backing material. Thin film modules are constructed from single sheets of thin film material and can be encapsulated in a flexible or fixed module. Most complete systems consist of a number of modules connected together to give a higher power rating.

Grid connection (inverter and mounting structures)

In grid connected systems, an inverter is used to convert the direct current (D.C.) output of the modules to alternating current (A.C.) that is then supplied to a building or to the national grid network. The conversion efficiency of inverters is greater than 90 % except at low insolation levels. 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 to provide the maximum power from the system. One inverter can be used for the whole array or separate inverters may be used to connect each 'string' of PV modules. Individual PV modules have also been developed with integrated inverters, usually referred to as 'ac modules'.

A wide range of **mounting structures** have been developed for building integrated systems, including PV facades, roof profiles, flat roof mountings, integrated glass-glass panels and 'PV tiles'.

Off-grid connection (batteries and charge controller)

For off-grid systems a storage battery is used to provide energy storage. Nearly all batteries used for PV systems are of the deep discharge lead-acid type. Nickel-cadmium batteries are also suitable and have the advantage that they cannot be overcharged or discharged, but are considerably more expensive. The lifetime of a battery varies but is typically between 5 and 10 years. A charge controller (or regulator) is used 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 or overcharging. An inverter may be used in off-grid applications, if there is the requirement for A.C. electricity.

Further details

More detailed descriptions of PV technology can be found on the IEA - PVPS website at: http://www.iea-pvps.org

Notes