IEA International Energy Agency

IMPLEMENTING AGREEMENT ON PHOTOVOLTAIC POWER SYSTEMS

TRENDS IN PHOTOVOLTAIC APPLICATIONS IN SELECTED IEA COUNTRIES BETWEEN 1992 AND 1998

REPORT IEA-PVPS 1-07: 1999

Cover photograph: The 1 MW_p PV project in Amersfoort, the Netherlands, taken by Jan van Ijken of Fotografie, Amersfoort.

This report has been prepared under the supervision of Task 1 by Donna Munro and Emily Rudkin of Halcrow Gilbert (GBR) on the basis of National Survey reports prepared by Task 1 experts and their assistants (see Annex B). The report has been funded by the IEA-PVPS Common Fund and has been approved by the IEA-PVPS Executive Committee.

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Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation among its 23 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems Programme is one of the collaborative R & D agreements established within the IEA. Since 1993, the 20 countries[1] participating in the Programme and the European Commission have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity. The Programme, whose mission is “to enhance the international collaboration efforts through which photovoltaic solar energy becomes a significant renewable energy option in the near future”, is divided into nine Tasks. This report has been prepared under Task 1 – Exchange and Dissemination of Information on Photovoltaic Power Systems, in order to contribute to this mission. The underlying assumption is that the market for PV systems will gradually expand from the present niche markets of remote applications and consumer products, to the utility market, through building-integrated and other diffused and centralised PV generation systems. This market expansion requires the availability of, and access to, reliable information on PV systems, applications and markets to be shared with the various actors.

“This is the Fourth International Survey Report published by the IEA-PVPS agreement and I trust that this document will be a source of useful and reliable information for an increasing number of decision makers and experts in the fast growing area of photovoltaic systems.”

Erik Lysen
Chairman PVPS Programme

Chapter 1 Introduction

1.1 Survey Report Scope and Objective

This report presents a description of the status of photovoltaic (PV) power systems in the 20 participating countries[1] of the IEA Photovoltaic Power Systems Programme. A survey of the status of PV power systems applications and markets in each country has been conducted every two years for the past six years and biennial reports published. The decision has now been taken to move to shorter annual reports and this is the first such report. This report presents an overview of PV power systems applications and markets at the end of 1998 and analyses the trends in PV power systems implemented between 1992 and 1998.

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, as well as changing applications within that market, in the context of business situations, policies and relevant non-technical factors in the reporting countries.

The survey report is not intended to serve as an introduction to PV power systems, nor is it intended to serve as a policy document. Its purpose is to present trends in PV applications in graphical and tabular form, with related analysis that will allow those interested in the use of PV power systems to draw their own conclusions about the state of a particular application and future prospects.

The survey reports are intended to meet the needs of 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. They should also give guidance to government officials responsible for setting energy policy and preparing national energy plans.

1.2 Survey Method

Data for this report were drawn from national reports supplied by each participating country by the respective national representative. A list of the reporting countries and national representatives is given in Annex B. The data collected covered the following main topics:

- The Market Today
- Demonstration and Field Test Programmes
- Industry Status and PV Systems Components
- Policy, Initiatives and Trends

Most national data supplied had an estimated uncertainty between 0 % and 20 %, with most data being accurate to within ±10 %. Data on national budgets was normally extremely accurate. Data on installed power was less accurate while data on production levels and costs varied in accuracy depending on the willingness of the national PV industry to provide data for the survey.

[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).

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 PVPS Programme Executive Committee.

1.3 Definitions, Symbols and Abbreviations

For the purposes of this report, the following definitions apply.

Demonstration Programme: a programme to demonstrate the operation of PV systems to the general public and potential users/owners.

Market deployment initiatives: initiatives to encourage the market deployment of PV through the use of market instruments such as green pricing, rate based incentives etc. They may be implemented by government, the financing industry, utilities etc.

MUSD: Million U.S. Dollars (see USD).

PV system: a photovoltaic system including photovoltaic modules, inverters, batteries and all associated installation and control components. When calculating installed photovoltaic capacity only systems with a capacity of 40 W_p or more have been included.

USD: U.S. Dollars. This is the currency used throughout the report. Exchange rates are given in Annex A. (see MUSD)

Watts Peak (W_p): W_p 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 AM1.5

Chapter 2 Implementation of PV Systems

This chapter identifies four primary applications for photovoltaic power systems, and looks at the market for each application. The final sections discuss PV demonstration and field test programmes in the reporting countries and the budgets allocated for market stimulation, demonstration and R&D programmes.

2.1 Applications for Photovoltaics

For the purposes of this survey, four primary applications for PV power systems were identified.

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 world-wide, particularly in developing countries, where they are often the most appropriate technology to meet the energy demands of rural communities. Off-grid PV systems generally offer an economic alternative to extension of the utility grid at distances of more than 1 or 2 kilometres from existing lines.

Off-grid non-domestic applications were the first economic application for terrestrial PV systems. They now provide power for a wide range of off-grid applications, such as telecommunications, water pumps, vaccine refrigeration, safety, control and protection devices and navigational aids, where small amounts of power have a high value and PV is cost competitive. As PV technologies keep improving, and costs decrease, so the size of this market should continue to grow. Australia, Japan and the USA, together account for 107 MW_p of installed off-grid non-domestic PV. Other key players are Canada, France, Germany, Italy and Korea each with over 2 MW_p installed capacity at the end of 1998.

On-grid 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 connected to the utility grid. The systems usually feed electricity back into the utility grid when electricity generated exceeds the building loads. These systems, which are increasingly being integrated into buildings or other structures, are likely to become commonplace in the next millennium. They are used to supply electricity to residential homes, commercial and industrial buildings, and are typically between 1 kW_p and 50 kW_p in size. There are a number of perceived advantages for these systems: distribution losses are reduced because the system is installed at the point of use, no extra land is required for the PV system and costs for mounting systems can be reduced if the system is mounted on an existing structure. Compared to an off-grid system costs are saved because energy storage is not required which also improves system efficiency.

On-grid centralised systems have been installed for two main purposes: as an alternative to centralised power generation from fossil fuels or nuclear, 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 and hence set up a number of demonstration projects. Demonstration plants have been set up in Germany, Italy, Japan, Spain, Switzerland and the U.S.A., 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

By the end of 1998 over 392 MW_p of PV power had been installed in the reporting countries. Note that for the purposes of this report, installed power refers to (terrestrial) PV applications with a peak rating of 40 W_p or more.

The breakdown of installed PV power by application in the reporting countries from 1990 to 1998 is shown in Figure 2.1. The unspecified cumulative installed power represents data unable to be separated into application, and mainly represents off-grid systems. The cumulative installed PV power has increased at an average annual rate of more than 25 % since 1992. It must be repeated that this report only covers the 20 countries participating in the IEA PVPS. The world-wide installed power will be significantly higher than the 392 MW_p installed in the reporting countries.

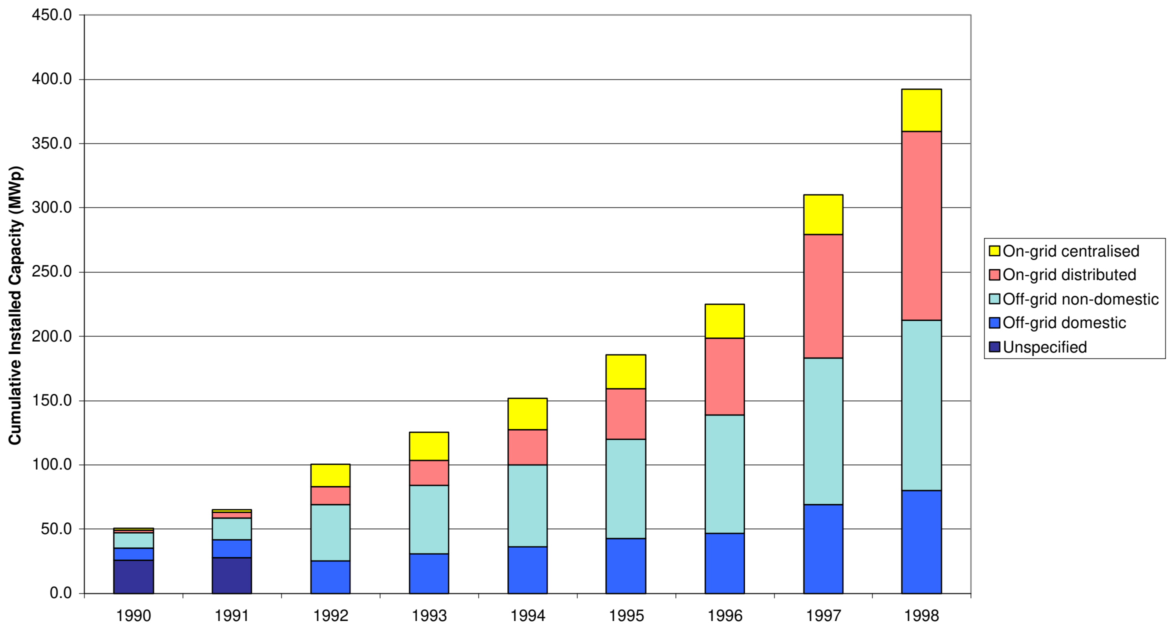
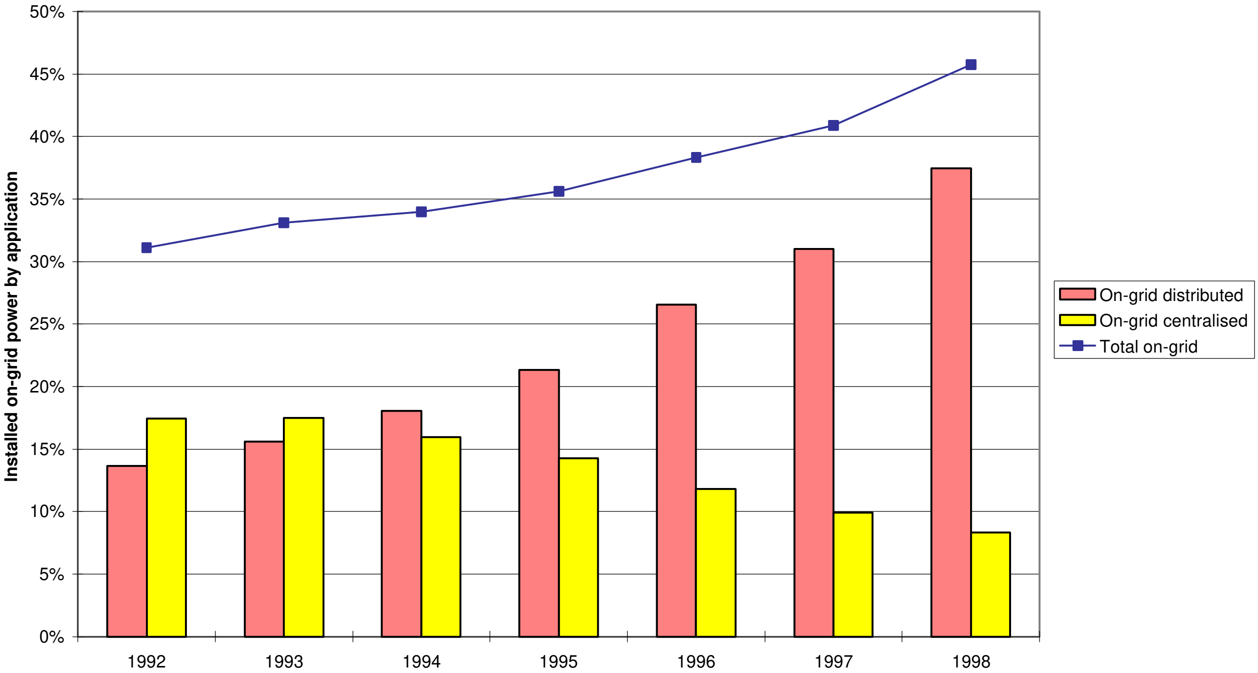


Figure 2.1: Cumulative installed PV power by application area in the reporting

Figure 2.1 shows that, until recently, the most widespread application for PV power systems has been in the off-grid sector. In 1992 off-grid applications accounted for 70 % of the installed power. However, in 1998 the on-grid installed capacity almost matched the off-grid capacity. The increase in the proportion of on-grid applications is shown explicitly in Figure 2.2. Since there have been few on-grid centralised systems installed the bulk of this increase is accounted for by the rapid growth of on-grid distributed systems.

Figure 2.2: Percentage of grid-connected PV power in the reporting countries (centralised and distributed)



The power installed by the end of 1998 in each country for each application is shown in Table 2.1 as well as the total installed PV power and total installed power per capita. The final column shows the power installed during 1998. It can be seen that over 81 MW_p was installed in the reporting countries in 1998. The cumulative historic power installed is shown in Table 2.2.

Table 2.1: Cumulative quantity of PV power installed in reporting countries as of the end of 1998 (kW_p)

Sector Country	Off-grid Domestic (kW_p)	Off-grid Non-Domestic (kW_p)	On-grid Distributed (kW_p)	On-grid Centralised (kW_p)	Total installed power (kW_p)	Total installed power per capita (W_p/capita)	Power installed in 1998 (kW_p)
AUS	5 960	15 080	850	630	22 520	1.22	3 820
AUT	487	674	1 630	70	2 861	0.36	653
CAN	1 378	2 825	257	10	4 470	0.15	1 090
CHE	2 210	190	7 630	1 470	11 500	1.64	1 776
DNK	35	140	330	0	505	0.10	83
DEU	2 900	6 300	37 300	7 400	53 900	0.66	12 010
ESP	5 010	910	600	1 480	8 000	0.20	900
FIN	2 100	300	46	30	2 476	0.49	434
FRA	5 600	2 260	140	0	8 000	0.14	1 881
GBR	108	254	328	0	690	0.01	101
ISR	88	200	6	14	308	0.06	43
ITA	5 210	5 100	780	6 590	17 680	0.31	971
JPN	450	52 200	77 750	2 900	133 300	1.07	42 000
KOR	306	2 410	266	0	2 982	0.07	507
MEX	9 789	2 195	2	0	11 986	0.13	986
NLD	2 476	954	3 050	0	6 480	0.42	2 444
NOR[1]	1 470	180	0	0	1 650	0.38	-
PRT[1]	384	102	17	0	503	0.05	-
SWE	1 823	433	114	0	2 370	0.27	243
USA	32 000	40 200	15 900	12 000	100 100	0.38	11 900
TOTAL	79 784	132 907	146 996	32 594	392 281	0.42	81 842

1 No data available for 1998, installed capacity as at 31 December 1997

Table 2.2: Historical perspective of the cumulative PV power installed in the reporting countries (kW_p)

Country	1992	1993	1994	1995	1996	1997	1998
AUS	7 300	8 900	10 700	12 700	15 700	18 700	22 520
AUT	524	768	1 063	1 361	1 739	2 208	2 861
CAN	960	1 240	1 510	1 860	2 560	3 380	4 470
CHE	4 710	5 775	6 692	7 483	8 392	9 724	11 500
DNK	0	85	100	140	245	422	505
DEU	5 619	8 900	12 440	17 790	27 890	41 890	53 900
ESP	3 950	4 649	5 660	6 547	6 933	7 100[1]	8 000
FIN	914	1 034	1 156	1 288	1 511	2 042	2 476
FRA	1 751	2 050	2 438	2 953	4 407	6 119	8 000
GBR	172	265	338	368	423	589	690
ISR	100	120	150	180	210	265	308
ITA	8 480	12 080	14 090	15 795	16 008	16 709	17 680
JPN	19 000	24 270	31 240	43 380	59 640	91 300	133 300
KOR	1 471	1 631	1 681	1 769	2 113	2 475	2 982
MEX	5 500	7 250	8 950	9 350	10 150	11 000	11 986
NLD	1 270	1 641	1 963	2 400	3 257	4 036	6 480
NOR[2]	300	600	900	1 150	1 400	1 650	1 650
PRT[2]	169	219	257	326	411	503	503
SWE	800	1 040	1 337	1 620	1 849	2 127	2 370
USA[3]	43 500	50 300	57 800	66 800	77 200	88200	100 100
TOTAL	106490	132817	169465	195260	242038	310 439	392 281

1 Installed capacity as at 31 May 1997
2 No data available for 1998, installed capacity as at 31 December 1997
3 The installation figures for the USA have been reduced by 20 % since the previous report to account for module and system exports of almost 4 MW_p/year by distributors.

By the end of 1998 over 90 % of the cumulative installed PV power in Australia, Canada, Finland, France, Israel, Korea, Mexico and Sweden was for off-grid applications. However the priorities within these countries varied, with more that 70 % of the installed power in Finland, France, Mexico and Sweden in the off-grid domestic sector, whilst in Korea more than 80 % of installed capacity was for off-grid non-domestic applications.

In contrast, the majority of systems in Germany and Switzerland are grid-connected, with on-grid capacity at 83 % and 79 % of total installed power respectively. Other countries with more than 50 % of installed PV power for on-grid applications were Austria, Denmark and Japan. In most countries with a high percentage of on-grid systems, the majority of on-grid applications were for distributed PV power, with the exceptions of Italy and Spain where 89 % and 71 % respectively of the on-grid PV power was centralised.

2.3 Major Projects, Demonstration and Field Test Programmes

This section provides an overview of the major projects, demonstration and field test programmes in operation in 1998 in the reporting countries. Their size, number and varied applications provide a good indication of the advances in PV power systems. All the reporting countries have installed demonstration plants, either funded through central or local government, the electricity utilities, the users or, in Europe, by grants from the European Union.

The demonstration and field test programmes in the reporting countries largely reflect the priorities of each country. A number of the larger and more sparsely populated countries such as Australia, Canada, Finland and France continue to provide most support to PV for off-grid applications. The renewable energy remote area power systems (RAPS) scheme in Western Australia, which aims to increase the reliability and usage of domestic renewable energy systems, offers grants of up to 4 800 USD for single households and 29 000 USD for communities. To date a total of 83 kW_p of PV has been installed under the programme.

In France, the demonstration and field test programmes were replaced by a series of dissemination programmes for off-grid PV in 1995. The public FACE (Fonds d'Amortissement des Charges d'Electrification) fund, which provides up to 70 % of the initial investment, had installed a total of 790 kW_p at 1 214 sites by the end of 1998. A pilot project for off-grid domestic PV systems in the summer ground of the Kitcisakik band, an isolated community in Canada, uses a prepayment controller to facilitate payment by each family. A total of twenty 150 W_p PV systems have been installed under this project.

In contrast, there is an increasing emphasis on PV systems that are integrated into the built environment, particularly in Japan and some of the densely populated countries of Europe. For example, in Austria a number of PV facades have been installed, the most recent being the 11.7 kW_p façade at the transformer station in Reiden. In Denmark, one of the most high profile projects has been the integration of 107 kW_p of PV on a block of apartments in Solgard. The project intends to demonstrate the integration of PV technology on existing buildings and to investigate non-technical aspects such as ownership, tariffs maintenance and user behaviour. Although in Sweden most PV systems are for off-grid domestic applications, the two largest systems installed in 1998 were the 6.8 kW_p Goteborg façade (using amorphous silicon cells) and the 11.8 kW_p façade and roof mounted PV system on a residential block in Kristianstad.

In Germany, where the main emphasis is on the market introduction of on-grid distributed PV systems, a number of large PV plants are also being built. The 1 MW_p roof-mounted system on the new trade fair centre at Munich-Riem was completed in 1997 and a 1 MW_p roof and façade integrated PV system at 'Mont Cenis' Side in Herne is scheduled to start operation in May 1999.

A number of countries have programmes to promote residential PV installations. In Japan, where approximately half of the on-grid distributed PV capacity in the reporting countries has been installed, the "Residential PV System Infrastructure Maintenance Programme" follows on from the "Residential PV System Dissemination Programme". These programmes have resulted in the installation of 9 244 residential PV systems between 1994 and 1997 with a further 8 229 houses signed up for 1998. In the USA, the Sacramento Municipal Utility District's (SMUD) Pioneer I programme resulted in the installation of 500 2-3 kW_p systems on customers roofs at subsidised prices. This has been followed by the Pioneer II programme which calls for 5 MW_p of PV to be installed. In Austria, 96 grid-connected PV systems received financial support from the federal government, specific regional governments and the electric utilities under the 200 kW_p Photovoltaic Rooftop Programme. The installations ran from 1992 to 1994 and have been followed up by an extensive monitoring programme to gain information about the efficiency and reliability of the system components. In the Netherlands, the Nieuwland project in Amersfoort, with a total of 1.3 MW_p of PV on the roofs of approximately 600 new homes and buildings, is near to completion. The first phase of the "City of the Sun" project, a new housing development project with a total of 5 MW_p of PV planned for integration into 2 600 houses, has started. Other residential PV programmes include the Italian 10 000 roof-top programme which has recently been launched and the private "Phebus" initiative in France that achieved the installation of 140 domestic PV systems by the end of 1998.

Other large scale PV programmes of note include the US Million Solar Roofs Initiative and a new programme in California, USA offering cash rebates of 3 USD/W_p to residential and commercial customers that installed grid-connected PV systems on investor-owned utility grids. In Japan, the "PV Field Test for Public Facilities" programme was completed in 1997 and resulted in the installation of 4 900 kW_p for various applications on a total of 186 public facilities. The "PV Field Test for Industrial Use" has followed in 1998 and aims to achieve cost reduction and system standardisation for PV systems installed in industrial facilities.

A number of countries have introduced demonstration programmes to integrate PV systems into school buildings in order to raise awareness to students. The Scolar Programme for Photovoltaics in the UK aims to install PV systems in 100 schools. Four options of size 600-690 W_p are available, with a government and industry funded subsidy of 60 %. In Germany, a number of initiatives are aimed at schools beginning with the Bayernwerk AG sponsored "Sun at School" programme from 1994-1997 that resulted in the installation of 544 1.1 kW_p grid-connected systems. In 1998 about 750 kW_p was installed by different institutions under this programme. Three on-grid PV systems were installed in Korea in 1998 including a 30 kW_p system on the roof of the student building of the KAIST (Korea Advanced Institute of Science and Technology) and a 12 kW_p system on a high school building. Programmes are also underway in Austria, Japan and Switzerland.

There have been fewer PV installations in the on-grid centralised sector with the only major projects of note being the installation of the 400 kW_p Singleton power station in Australia and the completion of the 10^{th} subfield (330 kW_p) of the ENEL-owned Serre plant in Italy.

Countries such as Canada and Israel have focussed on adapting PV to their specific climates. In Canada, a 3.2 kW_p PV façade demonstration system has been installed at the Nunavut Arctic College at a latitude of 63.45ºN under the PV for the North programme. This programme has contributed to the evaluation and improvements of PV technology so that systems can operate reliably in the harsh climate of Northern Canada. In Israel, a reverse osmosis desalination plant has been installed to produce 400 l/hr of fresh water to supply a small and remote community. The project aims to investigate the energy balance of a renewable hybrid system connected to a battery bank and a constant load and is powered by an off-grid 3.5 kW_p PV system, a 600 W wind turbine and a 5 kW diesel generator.

Some countries have concentrated on installing PV systems for specific applications. In Finland, Sonera Ltd have set up telecommunication base stations on the islands of Ulkokalla and Sokosti powered by autonomous PV systems. In 1998, more than 130 off-grid PV systems were installed in Korea for street lighting. In the Netherlands, Switzerland and Austria, PV demonstration systems have been installed on noise barriers mounted along motorways and railway lines.

2.4 Budgets for Market Stimulation, Demonstration and R&D

Table 2.3 shows the total budget for market stimulation, demonstration and R&D in the reporting countries between 1994 and 1998. It can be seen that most funding is used for R&D and market stimulation. The trend has been for the funds spent on market stimulation to increase, whilst the proportion of funding spent on R&D has decreased, from 72 % in 1994 to 42 % in 1998. Funding for demonstration projects has stayed fairly constant between 1994 and 1998. The total available budgets have increased from 350 MUSD in 1997 to 458 MUSD in 1998, although data was unavailable for Mexico, Norway and Portugal in 1998. Note that in 1997, the combined budget of these three countries was 1.8 MUSD which is only 0.5 % of the total budget.

Table 2.3: Budget breakdown for market stimulation, demonstration and R&D between 1994 and 1998 in MUSD.

Category	1994		1995		1996		1997		1998	
Market stimulation	51	18 %	99	29 %	154	55 %	164	47 %	214	47 %
Demo projects	28	10 %	28	8 %	22	8 %	27	8 %	51	11 %
R & D	208	72 %	215	63 %	105	37 %	159	45 %	193	42 %
Total	287		342		281		350		458	

The budget breakdown between the reporting countries in 1998 is shown in Table 2.4.

Table 2.4: Budget for R&D, demonstration projects and market stimulation in the reporting countries in 1998 in MUSD.

	AUS	AUT	CAN	DNK	FIN	FRA	DEU	ISR	ITA	JPN	KOR
R&D	1.0	1.9	0.5	0.2	0.	1.4	37.6	0.3	10.3	71.1	2.0
Demo	1.9		0.1	6.4					0.3	21.4	0.9
Market	0.8		0.4	1.4		8.2	18.4			132.5	
TOTAL	**3.7**	**1.9**	**1.0**	**8.0**	**0.4**	**9.6**	**56.0**	**0.3**	**10.6**	**225.0**	**2.9**

	NLD	ESP	SWE	CHE	GBR	USA
R&D	19.3		2.5	8.6	1.2	35.0
Demo	8.5	8.0	0.4	2.1	1.2	
Market	10.5	8.0		3.8		29.7
TOTAL	**38.3**	**16.0**	**2.9**	**14.5**	**2.4**	**64.7**

This shows that Japan's total budget of 225 MUSD is significantly higher than all the other reporting countries, with the market stimulation budget alone over 130 MUSD. Of the remaining countries, the largest total budgets for market stimulation, demonstration and R&D programmes were to be found in Germany, the Netherlands and the USA (56, 38 and 65 MUSD respectively).

Chapter 3 Industry and Growth

This chapter discusses the industries associated with manufacturing and installing PV systems and components. The production of PV modules and cells throughout the reporting countries is discussed and current trends in system prices are highlighted.

3.1 Photovoltaic Cell and Module Production

The sum total module production in 1998 of nations participating in the IEA Photovoltaic Power Systems Programme was 142.7 MW_p: this includes production for power applications smaller than 40 W_p but not for consumer applications.

Table 3.1 shows PV production and production capacity in 1998 separated according to world regions. The total module production of 142.7 MW_p in 1998 is an increase of 43 % from 1997 when total production was 100 MW_p. PV module manufacturing capacity was estimated to be 263.3 MW_p in 1998, an increase of 26 % since 1997 and 129 % since 1995.

Table 3.1 PV production in MW_p in the reporting IEA countries in 1998.

Region	Cell Production	Module Production				Module Production Capacity
		Amorphous	Crystalline	Other	Total	
USA	53.7	4.2	49.5	0.2	53.9	76.0
Japan	46.15	3.05	45.25	2.5	50.8	104.0
Europe	23.8	0.8	26.9	0	27.7	72.6
Rest	9.8	0	10.3	0	10.3	10.7
Totals	133.45	8.05	131.95	2.7	142.7	263.3

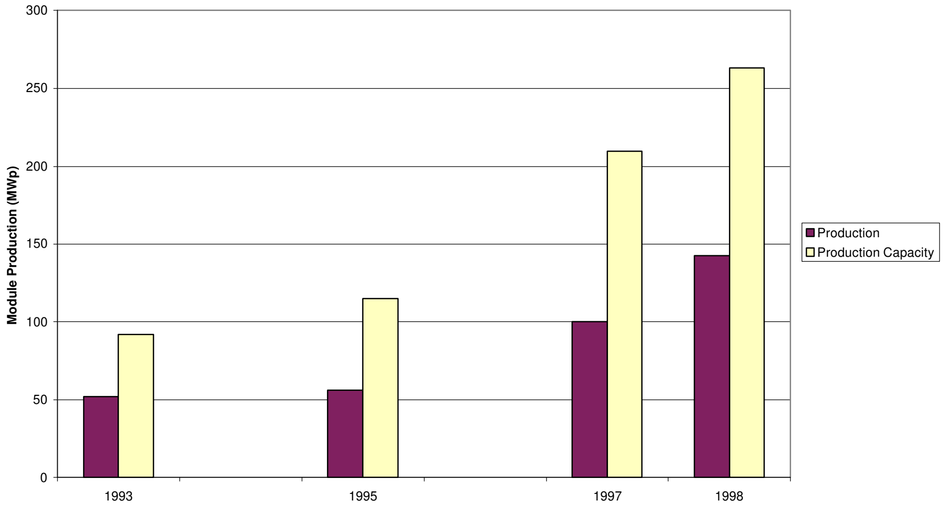
Commercial module manufacture is based mainly on crystalline and amorphous silicon technologies, although other technologies such as copper indium diselenide (CIS), cadmium telluride (CdTe) and edge fed growth cell (EFG cell) are starting to be commercially produced in Germany, Japan and the USA. The crystalline silicon technologies remain the most prevalent, constituting over 80 % of power module production manufacturing capacity at the end of 1998. See the PV Technology Note for a brief description of the different production technologies.

The total PV module production and production capacity in the reporting countries is shown in Figure 3.1 for the years 1993, 1995, 1997 and 1998.

The production figures are of course lower than the capacity figures. The utilisation of production capacity was 48 % in 1998. This figure is slightly misleading as the industry is rapidly expanding, and capacity that came on line during 1998 was not producing at all at the beginning of the year.

The module production capacity has increased significantly in a number of countries, including Germany, Japan and Spain with increases of 6.15, 23.0 and 5.5 MW_p respectively in 1998. The

production of PV modules remained concentrated mainly in Japan (36 %) and the USA (38 %), although the European countries accounted for 19 % of production and 28 % of capacity.
Figure 3.1: PV module production and module production capacity in 1993, 1995, 1997 and 1998



PV module manufacturers can be divided into two broad categories: firstly, those who purchase ready made PV cells and fabricate them into modules; secondly, vertically integrated manufacturers who manufacture their own cells and modules. Manufacturers of crystalline silicon modules fall into either of these categories whereas amorphous silicon module manufacturers are always vertically integrated as the distinction between cell and module is not relevant. In order to avoid ‘double counting’, modules are considered to be manufactured in a country only if the encapsulation takes place in that country.

Table 3.2 lists the module manufacturers in each of the reporting countries, showing cell and module production and module type. The additional information is the information available from the national reports which was provided on a voluntary basis.

PV Technology Note

Single crystal silicon cells are usually manufactured from a single crystal ingot most commonly grown by the Czochralski method. The ingot is doped with boron during the growth process to make it a p-type semiconductor. The ingot is then sawn into wafers and doped with phosphorous to make one side of the wafer n-type, thereby creating a p-n junction. Electrical contacts are attached to each side of the wafer, so that the cell can be connected to an external circuit. Although all crystalline silicon cells have some elements in common, modifications in cell design are steadily increasing the efficiency of single crystal cells and cutting their cost of manufacture.

While single crystal silicon remains the most efficient flat plate technology, it also has the least potential for cost reduction. PV cells made from multicrystalline silicon have become popular as they are less expensive to produce. Multicrystalline PV cell manufacture usually begins with a casting process in which molten silicon is poured in a rectangular block. This produces a block of multicrystalline silicon that is then sliced into wafers that are used to make the PV cells. Although multicrystalline cells are cheaper to produce than single crystal cells, they are slightly less efficient. 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 photovoltaic cells.

Other materials can also be used to make crystalline cells including Gallium Arsenide (GaAs) and Indium Phosphide (InP) which have maximum recorded laboratory cell efficiencies of 25.1 % and 21.9 % respectively.[2]

Thin film modules are constructed by depositing extremely thin layers of photosensitive materials on a low cost backing such as glass, stainless steel or plastic. As much less semiconductor material is required than for crystalline silicon cells, material costs are potentially much lower. Thin film production also requires less labour intensive handling as the films are produced as large, complete modules, and not as individual cells that have to be mounted in frames and wired together. Hence there is the potential for significant cost reductions with volume production. Thin films are made by sequentially depositing layers of material directly onto the chosen substrate. The first coating to be deposited is the front electrical contact, which is usually a thin layer of a metal oxide such as tin or zinc oxide. Each of the semiconductor layers is then applied before the individual ‘cells’ are formed by scribing through each layer in turn with a laser. A thin layer of base metal is then added to serve as a back contact.

The most fully developed thin film technology is hydrogenated amorphous silicon that was found to have photovoltaic properties in 1974. This is the material normally used in consumer appliances, 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 1980s 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%[2] and a record module efficiency of 10.4 %[2].

Other types of thin films can be made using polycrystalline silicon, gallium arsenide (GaAs), cadmium telluride (CdTe), and copper indium gallium diselenide (CIGS). Cadmium telluride modules can be produced by a variety of industrial processes that do not require expensive capital expenditure, such as electrodeposition and spray pyrolysis. CIGS and CdTe are promising PV materials, partly because of their high absorption of light.

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

Type	Typical (maximum recorded[2]) module efficiency (%)	Maximum recorded laboratory cell efficiency (%)[2]
Single crystalline silicon	12-15 (22.7)	24.5
Multicrystalline silicon	11-14 (15.2)	19.8
Amorphous silicon multijunction	6-7 (10.4)	13.5
Cadmium telluride	7-8 (9.2)	16.0

[2] ‘Solar Cell Efficiency Tables, Version 13’ M.A. Green, K. Emery, K. Bücher, D.L. King, S. Igari, Progress in Photovoltaics: Research and Applications, 1999 7, 31-37.

Table 3.2: Module manufacturers in the reporting countries

Country	Company	Cell Production (MW_p)	Module Production (MW_p)	Production Capacity (MW_p)	Module Type	Additional Information
AUS	BP Solar Australia	5.1	5.1	5.1	sc-Si	Cell, module and system manufacturer using imported wafers and screen printing technology.
AUS	Solarex	4.7	4.7	4.7	mc-Si	Cell, module and system manufacturer using imported wafers and screen printing technology. Expansion to a capacity of 5 MW_p planned by mid 1999.
CAN	Canrom				sc-Si	Manufacture a standard line of 30, 40 and 50 W_p modules which it distributes directly.
CHE	Atlantis Energie	0	0.4	1.2	sc-Si	Formerly Solution AG, Atlantis produces custom laminates using imported cells and 'Sunslates' roofing shingles.
CHE	Plaston AG	0	0.03		mc-Si	Plaston AG integrates imported cells into moulded plastic roofing tiles.
CHE	Star Unity	0	0.01	0.105	sc-Si	Star-Unity buys in cells and integrates them into roof tiles.
DEU	19 companies	2.4	6.78	24.9	sc-Si, mc-Si, EFG-Cell, a-Si	Data on cell and module production for individual companies is not available for publishing. The majority of modules produced are crystalline silicon with 0.4 MW_p of amorphous silicon produced in 1998.
DNK	Gaia Solar	0	0.035	0.33	mc-Si sc-Si	Standard and custom modules produced from imported cells.
ESP	Atersa	0	1	1.5	sc-Si	
ESP	BP Solar España	4.4	4.6	10.0	sc-Si	Involved in cell, module and system manufacture including production of 'Saturn' Laser Grooved Buried Grid cells. Modules available in a variety of colours.
ESP	Isofoton	0.643	3.37	5.0	sc-Si	Modules from 5 to 110 W_p in many different configurations.
FRA	Free Energy	0.4	0.4	1.0	a-Si	Thin film hydrogenated amorphous silicon modules (12 W_p ± 10 %) are produced for applications up to 100 W_p.
FRA	Photowatt	11.2	2.9	11.5	mc-Si	Photowatt is a vertically integrated company manufacturing multicrystalline silicon ingots, thin wafers, cells and modules (10 W_p to 100 W_p).
ITA	Eurosolare	0.7 3.3	0.4 1.8	3 (per shift)	sc-Si mc-Si	Fabricate multi crystal silicon wafers, single and multicrystalline cells and modules, and design and supply turnkey PV systems.
ITA	Helios Technology			2.5	sc-Si	Fabricate single crystal silicon cells and modules, and design and supply turnkey PV systems.
JPN	Canon	2.0	2.0	10	a-Si	Purchase of steel substrate and SiH_4 gas to produce a-Si cells and modules.
JPN	Daido Hoxan	1.0	1.0	1.0	sc-Si mc-Si	Purchase sc-Si and mc-Si substrate, which is used to manufacture cells and modules suitable for residential installations. Module sizes are typically 26.4, 45 and 53 W_p.
JPN	Kyocera	24.5	24.5	36	mc-Si	Purchase raw silicon scraps and cast substrate to manufacture cells and modules. Have developed 55 W_p and 65 W_p mc-Si modules for residential use.

Country	Company	Cell Production (MW_p)	Module Production (MW_p)	Production Capacity (MW_p)	Module Type	Additional Information
JPN	Mitsubishi Electric	1.1	0.8	10	mc-Si	Have started manufacturing.
JPN	MSK	0	3.0	3.0	mc-Si	Purchase mc-Si cells and manufacture into modules. Have commercialised a roof-integrated PV system.
JPN	Sanyo Electric	1.0 2.5	1.0 2.5	8 3	a-Si a-Si/sc-Si	Sanyo have developed a-Si roof-integrated systems and a-Si/sc-Si bifacial PV modules of sizes up to 190 W_p.
JPN	Sharp	6.15 7.80 0.05	6.15 7.80 0.05	25	sc-Si mc-Si a-Si	Sharp have commercialised sc-Si modules using a 17.5 % efficient cell. Developments include a PV system integrated with the building material and a thin type (15 mm) PV module rated at 125 W_p.
JPN	Showa Shell Sekiyu	0	2.0	6	sc-Si	Purchase of sc-Si cell for module manufacture. Have developed mass production technology for CIS solar cell.
KOR	LG Industrial Systems	0	0.344	0.4	sc-Si	LG Industrial Systems make PV modules (53 W_p) using solar cells supplied by LG Siltron.
KOR	Samsung Electronics	0	0.154	0.5	mc-Si	Assembles modules of 50 W_p and 60 W_p using cells supplied by Solarex USA.
NLD	Shell Solar Energy BV	0.8	4.0	6.0	mc-Si	Assembles mc-Si modules from cells that are partly manufactured in-house. Further expansion of production facilities is planned. Have standard 95 W_p AC module.
SWE	GPV	0	0.5 1.5	1 3	sc-Si mc-Si	Modules are produced from prefabricated cells. Standard modules are available with output powers of 40 W_p to 160 W_p. Also produce custom modules.
USA	ASE Americas	4.0	4.0	5.0	EFG ribbon Si	Multicrystalline silicon ingot is purchased, pulled into sheets and cut into 100 cm^2 slices. Both cells and modules are produced with 200 - 300 W_p modules as standard.
USA	Astropower	6.1 1.0	2.0 1.0	 4.0	sc-Si Si film	Purchases silicon wafers and processes them into cells. Have developed a new thin film silicon on low cost substrate.
USA	Siemens Solar Industries	20	14	24 3.0-5.0	sc-Si CIS	Fully integrated production with standard commercial modules produced in the range from 35 W_p to 120 W_p. Produced pilot quantities of CIS in 1998.
USA	Solarex	14.0 2.0	10.0 2.0	18 3+	mc-Si a-Si	Produces cast-ingot multicrystalline silicon cells and modules. 45 W_p to 60 W_p high voltage modules have been produced from a new 10 MW double junction a-Si plant.
USA	Solec International	4.0			sc-Si	Solec is owned by Sumitomo and Sanyo of Japan. They manufacture cells and modules (40 - 200 W_p), most of which are shipped to Japan.
USA	USSC	2.2	2.2	4	a-Si	Triple-junction amorphous silicon modules are produced for marine modules, framed power modules, a PV shingle and standard seam metal roofing material.
TOTALS		133.45	142.7	263.3		This total includes data from Germany and the smaller companies in the U.S.A. which is not given in this table.

Key: sc-Si is single crystal silicon; mc-Si is multicrystalline silicon; a-Si is amorphous silicon; CIS is copper-indium-diselenide; EFG ribbon Si is edge fed growth ribbon silicon.

In Germany a total of 19 companies produced PV modules in 1998, an increase from 15 companies in 1997. However total cell and module production did not increase significantly as many potential private PV plant owners were on hold for the government to publish the guidelines on the recently announced 100 000 roofs programme. It is anticipated that the cell production capacities will expand rapidly in the next two years and a number of companies have announced that they will open new production lines. At the end of the year 2000 the total cell production capacity is expected to reach 45 MW_p and 60 MW_p by the end of 2001.

In the United Kingdom there is one PV manufacturer which manufactures a-Si modules. There is no PV module production in Austria, Finland, Israel, Norway or Portugal. However approximately 50 % of the world demand for tedlar for PV modules is produced and exported by the Austrian manufacturer ISOVOLTA/Werndorf, Styria.

3.2 Balance of System Component Manufacturers and Suppliers

A specialised industry exists manufacturing PV balance of system (BOS) components such as battery charge controllers and inverters which convert the d.c. electricity generated by PV modules into a.c. As would be expected, those countries whose installed power is predominantly off-grid tend to have a BOS industry geared towards the manufacture of batteries and charge controllers, whereas in countries with predominantly on-grid power the industry tends to be geared towards the manufacture of inverters suitable for grid-connection.

There have been a number of recent advances in inverter technology including the development of transformerless inverters, module integrated inverters for a.c. modules of between 100 W and 300 W and string inverters of approximately 700 – 1500 W. The average price of inverters in most of the reporting countries remained similar to those in 1997, with little difference in the price of inverters up to 100 kVA in size (ranging from 0.7 USD/VA to 1.6 USD/VA) with the smaller inverters tending to be most expensive. The price dropped off considerably with the largest inverters (>100 kVA) to approximately 0.4 USD/VA. However, Germany, Japan, Korea, the Netherlands, Switzerland and the United Kingdom have seen reductions in the price of inverters since 1997, particularly in the 1-10 kVA range. This can mostly be attributed to increases in the number of inverters sold for on-grid distributed PV applications in these countries.

The lead acid deep cycle battery still remains the most common battery for PV applications. A number of battery manufacturers produce low antimony lead acid batteries to reduce self-discharge. In Australia, development of vanadium redox batteries, zinc/bromide batteries and ceramic fuel cells is being carried out with the view that they will be commercially available within five years. Several of the reporting countries manufacture battery charge controllers which perform the basic function of controlling how the battery is charged and preventing it from being too deeply discharged.

A number of countries reported the development of new concepts for building integrated PV systems. In Germany, glass manufacturing and façade construction companies are working in co-operation with architects and the PV industry. In Switzerland, low-cost mounting systems for flat-roof and sloping-roof PV installations are available.

3.3 System Prices

In general, large PV systems have lower system prices per W_p than smaller capacity systems. Prices for entire PV systems vary widely and depend on a range of factors including system size, location, customer and the technical specification. For building integrated systems, the cost of the system varies significantly depending on whether the system is part of a retrofit or is integrated into the roof structure of a new building. Overall the average prices of PV systems in 1998 remained similar to those in 1997 although a number of countries saw significant price reductions in some of the application sectors.

- System prices in the off-grid 40 to 1000 W_p sector ranged from 7.8 to 24.0 USD/W_p. The corresponding prices in 1997 were 8.4 to 52.8 USD/W_p.

- For larger (>1 kW_p) off-grid systems prices ranged from 9 to 28.6 USD/W_p compared to 1997 prices of 8 to 35.7 USD/W_p with a marginally different size range of 1-4 kW_p.

- The price range for on-grid 40 W_p - 10 kW_p systems was 5.5 to 25.2 USD/W_p compared to 5 to 20 USD/W_p in 1997 with a slightly different size range of 1-4 kW_p. A number of the European countries including Denmark, Germany and Switzerland saw price reductions of up to 20 % in this application sector.

- The price range for systems larger than 10 kW_p was 4.8 to 21.4 USD/W_p compared to 5.8 to 35.7 USD/W_p in 1997.

These prices do not include recurring charges after installation such as battery replacement or operation and maintenance. The highest prices tended to be in the countries with the lowest amount of installed PV power where PV is mostly used for niche applications or demonstration projects. However, prices were not necessarily high for all applications in these countries. For example, in Denmark prices were generally high with the exception of small on-grid systems, which may be attributed to their roof-top programme. Similarly, some countries with large markets had relatively high prices for some applications. The system prices were the lowest in Australia, the United States, Germany and the Netherlands, each of which have in excess of 5 MW_p of installed PV capacity. The prices associated with on-grid systems were generally significantly lower than those for off-grid systems because no batteries and associated components are necessary.

Chapter 4 Framework for Deployment

This chapter looks at new initiatives in promoting photovoltaic systems, the effects of both direct and indirect policy issues on the PV market and the standards governing the connection of PV systems to the grid.

4.1 New Initiatives in Photovoltaic Power Systems

A wide variety of initiatives for promoting the use of photovoltaics, or renewable energy in general, exist in the reporting countries. Market deployment initiatives are beginning to replace national demonstration programmes in a number of countries, particularly where it is felt that the market has matured sufficiently and a particular application of PV is ready for stimulation.

Table 4.1 looks at the new initiatives in each of the reporting countries, highlighting the main promotional initiatives, the utility and public perceptions of PV and some major projects and planned developments.

Table 4.1: New initiatives in reporting countries

Country	Promotional Initiatives	Utility and Public Perceptions	Major New Initiatives and Planned Developments
AUS	An increasing number of electricity retailers are offering net metering for domestic PV installations. A 20 % “cashback” for residential roof top installations and 40 % for public buildings is available in NSW. The WA state government offers 75 % grants for renewables used in remote area power systems. New utility Green Power schemes are being developed in Victoria, WA and South Australia. Such schemes continue to operate very successfully in NSW.	Utilities show increasing interest in PV. Grid connected PV is now accepted by the utilities due in part to the availability of guidelines for connection. Public support continues although PV still finds it difficult to compete with conventional energy due to electricity price falls and falling taxes on fuels.	1 kW_p roof systems installed at Newington Solar (Olympic) Village. The target of 2 % new renewables by 2010 has been set, however it is unlikely that PV will be promoted through this mechanism. New production facilities for thin film silicon (Pacific Solar) and titanium dioxide (Sustainable Technologies Australia) planned by 2000. 2 MW_p concentrating PV system at Broken Hill and 70 kW_p roof mounted system at the Sydney Superdrome planned.
AUT	Some regional governments subsidise the erection of PV systems under environmental programmes (a maximum of 20 000 USD per application). Tariffs vary between utilities, ranging between 0.032 - 0.8 USD per kWh.	Most utility companies have installed PV systems for demonstration or for supply to isolated areas. Utilities continue to support public authorities and schools in planning and installing systems. Public support for PV shown in green electricity programmes requiring contribution of about 45 USD per year.	
CAN	No specific incentives, rates or tariffs for PV. No legal requirements for utilities to buy back power. Limited net metering. Accelerated depreciation for systems >3 kW_p		
CHE	A major factor in promoting PV	About 50 utilities are ready to	The Government’s “Energy

	is the solar "stock-exchanges" that enable consumers to buy PV at a price which covers production costs of electricity from new PV installations.	supply PV power via the stock-exchange scheme to their 1.6 million customers, of which about 1 % are willing to pay a premium for solar electricity. 150 new installations were constructed under this scheme in 1998.	2000" programme and the Swiss Utilities Association are working to ensure that all electricity consumers are able to profit from PV generated electricity.
DNK	Grants for the commercial sector to install PV have increased from 26 % in 1997 to 36 % in 1998, although there have been few results to show to date. Net metering for private households and institutions was introduced in 1998, initially for a test period of four years. All uses of energy are taxed by energy tax, CO_2 tax/green tax, resulting in high consumer prices of about 0.20 USD per kWh for domestic users.	Polls carried out by the DEFU (the Federation of Danish Utilities research branch) reveal a high consumer interest in PV and a willingness to pay more for green electricity. The utilities have created a national PV working group.	A 300 roof-top programme is being implemented by the utility EnCon, and PV is receiving more interest on a political level. With the liberalisation of the electricity market, a national PV strategy may be expected in the near future.
DEU	Market introduction models are widespread on the government and state levels including subsidies, loans and tax benefits. 10 of the 16 Federal States provide support for PV installations. Grants are available in some areas in combination with rate based incentives. Net metering will be allowed by some municipal utilities, from January 1999.	Utilities are obliged to pay a basic tariff of 0.1 USD per kWh by law.	The 100000 Roofs Programme was announced in December 1998. It offers a low interest loan for 10 years with no repayments in the first 2 years. About 600 MUSDand an installed power of 300 MW_p is expected within 6 years.
ESP	Local electricity utilities must purchase renewable energy supplied electricity at prices set by national authority – 0.44 USD/kWh for PV installations <5kW_p, 0.24 USD/kWh for PV installations >5 kW_p.	Several Spanish utilities have invested substantially in grid-connected PV projects such as Iberdrola. Endessa and Union Fenosa are two of the main partners in the 1 MW Toledo PV plant. The general public perception is positive particularly due to the low visual impact of PV.	The Energy Saving and Efficiency Programme (PAEE) is run by the different regions in Spain. The PAEE subsidises PV installations to a maximum of 4.1 USD/W_p for on-grid systems and 8.2USD/W_p for off-grid systems.
FIN	No promotional initiatives as such are available. However, the Ministry of Trade and Industry can grant investment subsidies of up to 40 % of the expenses of investment on renewable energy demonstration projects, e.g. photovoltaic systems. The subsidy is granted to utilities and enterprises only.	With the introduction of "green electricity" utilities are becoming increasingly interested in demonstrating building integrated PV systems. Liberalisation of the energy market has stimulated public interest in PV.	A National Renewable Energy Promotion Programme is starting that will provide incentives for promoting PV. Real estate and housing associations may receive investment subsidies.
FRA	FACE funds provide public subsidies for rural electrification. Since 1995 off-grid renewable	The national electricity utility EDF is involved in the promotion of PV systems in off-	In 1998, the French government decided to reactivate the promotion and development of

	energy systems (wind and PV) have been eligible for FACE funds where grid extension is more expensive. The PV industry has also taken advantage of investment tax exemptions in overseas departments, (not targeted at PV). In 1996 the French Ministry of Industry recommended that on-grid distributed systems be allowed net metering.	grid rural areas.	renewable energy sources. New funds will be available from the beginning of 1999.
GBR	A Climate Change Levy is being discussed that would be used to support the uptake of renewable energy sources.	The 16th European PV Solar Energy Conference will be held in Glasgow, Scotland in 2000. This will raise both public and business awareness of PV.	The British PV Association has drawn up a strategy document "PV in the UK – Facing the Challenge" to assist in meeting targets of 10 % of all electricity generated by renewables by 2010 and to raise the profile of PV.
ISR	The government supports only R&D development of PV.	A number of small thefts have created a negative image of PV applied to public projects. However, public awareness continues to grow.	It is forecasted that the Israeli economy will come out of decline and it is hoped that this will result in more support for PV projects.
ITA	There are currently no preferential tariffs, utility paying incentive rates, financing packages or specific interest rates for PV. However, tax reductions of 41 % of the investment cost of PV plants are available and a VAT reduction from 20 % to 10 %.	ENEL has a comprehensive R&D programme for promoting PV, including testing at the Adrano plant. Some municipal utilities have started small demonstration programmes. The public perception of PV remains good.	A 10 000 PV roof top programme has been announced and is expected to start towards the end of 1999. The programme, aimed at installing 50 MW_p of small PV plants in five years will be financed by the Italian Government.
JPN	The local energy taxation system stipulates that the taxable amount of a fixed property can be reduced to 5/6 for three years if PV is installed. A further tax scheme offers either a tax credit of 7 % of the acquisition value of the PV system or 30 % depreciation for the first year. Some financing institutions offer preferential loans to homebuyers for PV systems.	Net metering has been available since 1992. In 1997, Tokyo Electric Power Company established a new subsidy system to support R&D on PV and a subsidy of half the cost of residential PV installations. Public support for PV is growing as can be seen in the Residential PV System Dissemination Programme.	The target capacity for PV was amended in 1998 upwards from 4 600 MW to 5 000 MW by 2010.
KOR	No initiatives for the promotion of PV are currently available.		
MEX	Government grants are available to isolated and poor communities for rural electrification.		
NLD	In 1998 Greenpeace launched a nationwide campaign, Solaris, to develop a consumer market for small on-grid PV systems with an offer of one 100 W_p AC module for less than 500 USD. Most utilities accept net	Strong support for PV by both the public and utilities. The Solaris project has contributed to public support of PV. Three utilities have launched a joint project together with the industry, "PV Groei", focussing	The new government announced an extra budget of 29 MUSDto be spent on market development of PV in the next four years. Future projects will concentrate on BiPV development and small PV systems using AC modules.

	metering.	on small on-grid PV systems with 4 AC modules. The "green current" programme offers electricity generated from renewables with prices typically 30 % above that generated from fossil fuels.	Further developments in various fiscal and taxation instruments expected making them more beneficial for investments in renewable energy.
SWE	No promotional initiatives such as preferential tariffs or a reduction of sales tax are available. New installations of significant size are likely to be considered demonstration systems and receive government funding.	The general view of PV as a long term sustainable renewable energy technology is positive. Utilities consider that PV is more suited in countries where the supply of solar energy and the electricity demand is better matched. It is considered by some utilities as a long term option for distributed generation.	
USA	Grants for PV systems in 12 states, loans in 15 states. Over 22 states now approve net metering. Green pricing available from 10 utilities in 8 states. Tax benefits in various states.	The Sacramento Municipal Utility District (SMUD) PV Pioneer II programme has commenced with over 5 MW_p of systems planned for next 7 years	The Million Roofs Initiative, a ten year plan to stimulate the deployment of one million PV and solar hot water systems, has commenced. This includes initiation of a loan programme and government grants to participating partners. Planned developments include bringing the United Solar Systems and Solarex a-Si plants to full capacity, completion of the AstroPower Silcon-Film^{TM} plant, operation of the BP Solar cadmium-telluride plant, operation of the PVI concentrator plant and completion of the First Solar cadmium-telluride plant.

Note: Information on Norway and Portugal is not provided in this table as they did not provide National Survey Reports for 1998.

4.2 Indirect Policy Issues and their Effect on the PV Market

The national reports identified a number of issues that indirectly affect the implementation of PV systems. Many of the reporting countries have implemented national policies and programmes to meet the reduction in carbon emissions to 5 % below 1990 levels by the year 2000 as agreed at the 1997 Kyoto Conference of Parties to the Framework Convention on Climate Change. In Japan, a number of new government laws and guidelines have been established, including the "Basic Guideline and Law for Promotion Measures to Arrest Global Warming." The Climate Change Action Fund may be used to promote PV in Canada, and in the UK a climate change levy is being discussed. A number of countries have set national targets for the proportion of electricity to be supplied by renewable sources. In 1998 a law was passed committing Austria to achieve 5 % of electricity generation from specified renewables by 2005. In the Netherlands a goal of 10 % has been established for renewables by 2020.

Utility privatisations and restructuring, creating increased levels of competition, are also on-going in a number of countries. Although in most countries this has not yet had any impact on the implementation of PV, in Canada it has caused attention to be temporarily focussed away from renewables and in Austria the new electricity market rules have temporarily paralysed decisions relating to the funding of renewables. In the United States, the deregulation has had benefits including green pricing, net metering and integrated resource planning mandates although this varies from state to state.

CO_2 and energy taxes are being discussed and implemented in a number of countries. In Italy, a pollution tax has been introduced from which a share of the receipts will be devoted to their PV programme. In Germany, an ecological tax reform comes into force on 1 April 1999. Taxes on electrical power from renewable energy will be reinvested in support of all renewables. The PV support programme in Denmark receives funding from the CO_2 tax on electricity. An emission-trading scheme is being discussed in Australia which may result in trading in renewable energy credits. In Switzerland, levies on non-renewable forms of energy and funding for renewables, including PV, are being discussed at government level.

4.3 Standards and Codes

The increasing use of PV power systems requires a series of national or international standards in order to facilitate the construction, grid-connection and operation of PV power systems. By the end of 1998, specific regulations and guidelines governing the grid connection of PV systems had either been developed or were in place in a number of countries, including Australia, Austria, Germany, Japan, the United Kingdom and the United States. In Italy, a new standard for connection of generators to the low voltage and medium voltage networks has been established and in Sweden, the regulations were revised for the connection of small electric power units. Some countries had no specific standards or regulations concerning the grid-connection of PV systems, but used regulations applicable to other generators, such as small hydro or wind power. In the Netherlands and Canada, guidelines for electricians and inspectors for grid-connected installations are being developed. In France, a handbook on "Specifications for the use of renewable energies in decentralised rural electrification" has been developed and submitted to the International Electrotechnical Commission (IEC). This document with amendments will become an international standard.

The utilities in a number of countries have been satisfied with the protection offered with inverters, whilst others have insisted on additional protection between the inverter and the grid. Specific guidelines relating to the safety of PV products and systems have been developed in Canada, Germany, Switzerland and the United States. In Denmark, schemes have been established for the certification of components and systems, and in the United Kingdom type test procedures for PV inverters are being developed. Other developments include wiring standards in Australia, AC module issues in Switzerland, and a product certificate for PV integrated roofing materials for sloped roofs in the Netherlands.

Chapter 5 Summary of Trends

This report has taken data from the national reports of the reporting IEA countries to produce a summary of the trends in PV power systems applications and the PV market for 1998. Information was also taken from the first, second and third International Survey Reports which covered the years 1992 to 1997 and updated where this has been appropriate and possible.

For the purposes of the survey, four primary applications for PV power systems were identified: off-grid domestic, off-grid non-domestic, on-grid distributed and on-grid centralised. A summary of installed power and module production is given in Table 5.1.

Table 5.1: Installed PV power and module production in the reporting countries.

Year	Cumulative installed power and percentage increase						Power installed per year	Module production in year
	Off-grid		On-grid		Total			
	MW_p	%	MW_p	%	MW_p	%	MW_p	MW_p
1992	75		31		106			
1993	91	21	42	35	133	25	27	52
1994	109	20	51	21	160	20	27	
1995	129	18	66	29	195	22	35	56
1996	154	19	88	33	242	24	47	
1997	183	19	127	44	310	28	68	100
1998	213	16	179	41	392	26	82	143

In the period 1992 to 1998, the installed PV power in the reporting IEA countries has grown at an average annual rate of over 25 %. The cumulative power installed in the reporting countries is 392 MW_p with over 80 MW_p of this power installed in 1998.

Off-grid systems have been installed in all of the reporting countries, mainly for low power applications. The greatest share of the market for off-grid domestic systems is in the United States and Mexico and for off-grid non-domestic systems in Australia, Japan and the United States. Countries that have more than 90 % of their installed PV power in the off-grid sector are Canada, Finland, France, Israel, Korea and Sweden.

The proportion of PV power which is on-grid has increased from 30 % in 1992 to 46 % in 1998. The bulk of this increase is accounted for by a large increase in on-grid distributed systems, often promoted by demonstration and market incentive programmes. In Germany and Switzerland, 83 % and 79 % of the installed power was grid-connected respectively. With the exceptions of Italy and Spain, the majority of on-grid applications were for distributed PV power in all countries with a large quantity of on-grid systems.

The national demonstration programmes in the reporting countries largely reflect the priorities of each country. There is an increasing emphasis on on-grid distributed systems, particularly in densely populated countries where PV is being integrated into existing structures such as building façades, roofs and sound barriers. A number of countries have programmes to promote residential PV installations, most notably Japan, the United States and the Netherlands. Programmes to integrate PV systems into school buildings in order to raise the awareness of students are currently underway in Austria, Germany, Japan, Switzerland and the United Kingdom.

The total budgets for market stimulation, demonstration and R&D in the reporting countries have increased from 350 MUSD in 1997 to 458 MUSD in 1998. The proportion of funds spent on market stimulation have continued to increase, from 18 % in 1994 to 47 % in 1998, whereas the funds spent on R&D have decreased. The proportion of funding spent on demonstration projects stayed fairly constant between 1994 and 1998.

In 1998, the total module production of countries participating in the IEA PVPS Programme was 142.7 MW_p: (excluding modules for consumer applications). This is an increase of 43 % from 1997 when total production was 100 MW_p. PV module and cell manufacturing capacity was estimated to be 263 MW_p in 1998, compared with 210 MW_p in 1997. Modules are manufactured in all the reporting countries except for Austria, Finland, Israel, Mexico, Norway and Portugal.

The prices for PV systems varied widely within the reporting countries, depending on a range of factors including system size, customer and the technical specification. The system prices in the off-grid, 40 to 1000 W_p sector ranged from 7.8 to 24. USD per W_p, compared to 9. to 28.6 USD per W_p for larger (1-4 kW_p) off-grid systems. The corresponding prices in 1997 were 8.4 to 52.8 USD per W_p for the 40-1 000 W_p systems and 8 to 35.7 USD per W_p for the larger systems
The prices for on-grid systems larger than 10 kW_p are 4.8 to 21.4 USD per W_p compared to 5.8 to 35.7 USD per W_p in 1997. The price range for on-grid systems of size 40 W_p to 10 kW_p was 5.5 to 25.2 USD per W_p. The highest prices occurred in countries where PV was mostly used for niche applications or demonstration projects.

A large number of new initiatives were reported, including an increasing number of green electricity schemes, net metering, specific tariffs for PV and government grants for installations. In general, the utilities are showing an increasing interest in PV with utilities in several countries involved in the installation of demonstration projects and large scale implementation programmes.

Many countries have implemented national policies and set targets for the proportion of electricity to be supplied by renewable sources. This may be attributed in part to the 1997 Kyoto Conference of Parties to the Framework Convention on Climate Change. A number of countries are discussing or implementing CO_2 and energy taxes that are reinvested into PV and other renewables.

ANNEX A
EXCHANGE RATES

The table below lists the participating countries, corresponding ISO country and currency codes, and the exchange rates used to convert national currencies. 1998 exchange rates are generally used.

Table A.1 - Exchange Rates

COUNTRY	ISO COUNTRY CODE	CURRENCY and ISO CODE	EXCHANGE RATE (1 USD=)
Australia	AUS	Dollar (AUD)	1.67
Austria	AUT	Schilling (ATS)	12.5
Canada	CAN	Dollar (CAD)	1.483
Denmark	DNK	Krone (DKK)	7
Finland	FIN	Markka (FIM)	5.34
France	FRA	Franc (FRF)	5.88
Germany	DEU	Mark (DEM)	1.7825
Israel	ISR	New Shekel (ILS)	4.159
Italy	ITA	Lira (ITL)	1800
Japan	JPN	Yen (JPY)	120
Korea	KOR	Won (KRW)	1 403
Mexico	MEX	Peso (MXP)	9.0
Netherlands	NLD	Guilder (NLG)	1.98
Norway	NOR	Krone (NOK)	7.7
Portugal	PRT	Escudo (PTE)	183.8
Spain	ESP	Peseta (ESP)	149.53
Sweden	SWE	Krona (SEK)	7.951
Switzerland	CHE	Franc (CHF)	1.45
United Kingdom	GBR	Sterling (GBP)	0.625
United States	USA	Dollar (USD)	1
European Union		European Currency Unit (XEU)	0.88

ANNEX B

IEA PVPS TASK I

EXPERTS

Australia	Greg Watt, Australian PVPS Consortium
Austria	Georg Baier, Verbund
Canada	Raye Thomas, NewSun Technologies Ltd.
Denmark	Peter Ahm, PA Energy A/S
Finland	Petri Konttinen, Helsinki University of Technology
France	André Claverie, ADEME
Germany	Peter Sprau, WIP
Israel	David Berman, The Ben Gurion National Solar Energy Centre
Italy	Salvatore Guastella, CONPHOEBUS - ENEL
Japan	Masao Kando, NEDO
Korea	Kyung-Hoon Yoon, KIER
Mexico	Jaime Agredano Diaz, IIE
Netherlands	Astrid de Ruiter, NOVEM
Norway	Alf Bjørseth, ScanWafer AS
Portugal	Gina Pedro, DGE
Spain	Manuel Blasco, UNESA
Sweden	Lars Stolt, Uppsala University
Switzerland	Pius Hüsser, Nova Energie GmbH
United Kingdom	John Reeves, EA Technology Ltd
United States of America	Charles W Linderman, Edison Electric Institute

In some cases, the Task I expert was assisted by one or more experts from their respective countries.
These experts are listed below.

Australia	Muriel Watt, University of NSW
Canada	Lisa Dignard, Canmet's Energy Diversification Research Laboratory
Denmark	Bent Sørensen, Roskilde University
Germany	Ingrid Weiβ, WIP
Italy	Salvatore Castello, ENEA; Anna Delillo, ENEA
Japan	Eiichi Waki, NEDO; Shuji Yamamoto, PVTEC
Korea	Jinsoo Song, KIER
Netherlands	Leendert Verhoef, VSEC
Sweden	Karin Granath, Uppsala University
Switzerland	Alan C. Hawkins, A.C. Hawkins Consulting & Services
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