IEA INTERNATIONAL ENERGY AGENCY

TRENDS IN PHOTOVOLTAIC APPLICATIONS

Survey report of selected IEA countries between 1992 and 2002

PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

Report IEA-PVPS T1-12:2003

TRENDS IN PHOTOVOLTAIC APPLICATIONS
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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.

Following its 10 year anniversary in early 2003, IEA-PVPS is pleased to publish the 8th issue of the International Survey Report (ISR) on trends in photovoltaic applications. This report is the first publication marking the beginning of the second decade of international co-operation within IEA-PVPS. Photovoltaic products, applications and markets continue to expand rapidly all over the world, in parallel with a growing industrial manufacturing capacity. Based on the analyses performed on 11 consecutive years of data, this ISR allows a continuous overview of the major trends and specific initiatives in this increasingly global market. IEA-PVPS will continue to track these trends and fulfil its information role as an independent, reliable and globally active network of expertise. Striving for an even more widespread dissemination of information on the results obtained within IEA-PVPS, this publication will hopefully contribute to raising the awareness about photovoltaics in various target groups.

Stefan Nowak
Chairman IEA-PVPS Programme

This report has been prepared by IEA-PVPS on the basis of National Survey reports prepared by Task 1 participants and their assistants.
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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 2003

Atrium Hall, STMICROELECTRONICS, Plan-les-Ouates/GE, Switzerland

Introduction

Survey report scope and objective

As part of the work of the IEA-PVPS programme, annual surveys of photovoltaic (PV) power applications and markets are carried out in the 20 participating countries[1]. The objective of the survey reports is to present and interpret trends in both the PV systems and components being used in the PV power systems market and the changing applications for these products within that market. These trends are analyzed 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. It is prepared to assist those responsible for developing the strategies of businesses and public authorities, 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.

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

This report presents the results of the eighth international survey. It provides an overview of PV power systems applications and markets in the reporting countries at the end of 2002 and analyzes trends in the implementation of PV power systems between 1992 and 2002.

Survey method

Key data for this publication were drawn from national survey reports[2], which were supplied by representatives from each of the participating countries. These national reports can be found on the website www.iea-pvps.org.

Following technical review by the national representatives, the report was approved by the IEA-PVPS Executive Committee. A list of the national authors is given at the end of this publication.

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 in watts (W). This represents the rated power of a PV module or system under standard test conditions of 1 000 W.m^{-2} irradiance, 25 °C cell junction temperature and solar reference spectrum AM 1,5. The term PV system includes the modules, inverters, batteries and all associated mounting and control components as appropriate. Currencies are either presented as the current national currency (where it is considered that the reader will receive the most benefit from this information) or as US dollars (where direct comparisons between countries' information is of interest). Care should be taken when comparing USD figures in this report with those in previous reports because of exchange rate movements. The exchange rates used for the conversion from national currencies to USD in 2002 are given at the end of this report.

Kriegerhorn, Austria Building integrated PV, Courtesy of ATB Becker

[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 Spain this year; production data were supplied by ASIF.

1 Implementation of Photovoltaic Systems

1.1 Applications for photovoltaics

There are four primary applications for PV power systems:

PV for Rural electrification at an isolated community, Mexico

Off-grid domestic systems provide electricity to households and villages that are not connected to the utility grid. 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 off-grid communities. Off-grid domestic systems generally offer an economic alternative to extending the electricity distribution grid at distances of more than 1 or 2 km from existing power lines.

Photo courtesy of Wolfgang Meike, NT Centre for Energy Research, Australia

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 telecommunication, water pumping, vaccine refrigeration, navigational aids, aeronautical warning lights and meteorological recording equipment. These are applications where small amounts of electricity have a high value, thus making PV commercially cost competitive with other small generating sources.

Ieodo Ocean Research Center, Korea

Grid-connected distributed PV systems are relatively recent applications 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 to become commonplace. They are used to supply electricity to residential dwellings, commercial and industrial buildings, and are typically between 0,4 kW and 100 kW in size. The systems typically feed electricity back into the utility grid when the on-site generation 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 energy storage is not generally required, a factor that also improves system efficiency and decreases the environmental impact.

Hills Garden Kiyota, Japan Each PV system can provides about one third of electricity consumed in a household

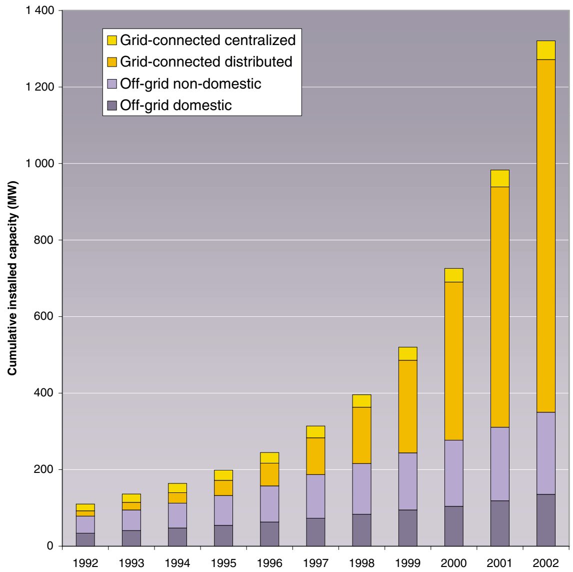
Grid-connected centralized systems have been installed for two main purposes: as an alternative to conventional centralized power generation, or for strengthening the utility distribution system. Utilities in a number of countries are investigating the feasibility of these types of power plants. Demonstration plants have been installed in Germany, Italy, Japan, Spain, Switzerland and the USA, generating reliable power for utility grids and providing experience in the construction, operation and performance of such systems.

1.2 Total photovoltaic power installed

It should be noted when interpreting results that one country installed more capacity in 2002, than the remaining countries combined. It should also be noted that in 2002, three countries accounted for 85 % of the total installed capacity and more than 92 % of new capacity; when these surveys commenced, a decade ago, the main three countries only accounted for 64 % of the market.

By the end of 2002, a cumulative total of about 1 330 MW of PV power capacity had been installed in the IEA-PVPS countries. The increase in installed capacity is shown in Figure 1, broken down by the four primary applications for PV. This represents a significant proportion of worldwide PV capacity. Since 1999, between 70 % and 86 % of PV production in the reporting countries can be accounted for by the capacity installed in the IEA-PVPS member countries, and the IEA-PVPS countries have accounted for more than 90 % of global PV production.

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



The annual rate of growth of PV installed has varied between 20 % in 1994 and 40 % in 2000. However, the rate of growth between 2001 and 2002 (34 %) was similar to the rate of growth between 2000 and 2001 (36 %). As in previous years, the majority of the growth in 2002 was in Japan and Germany, with these two countries alone accounting for 79 % of reported capacity installed during the year. In terms of installed power per capita, Japan continues to lead the way with 5 W per capita, significantly above that of Germany and Switzerland at 3,4 and 2,7 W per capita respectively.

Figure 2 - Percentages of PV power applications in the reporting countries

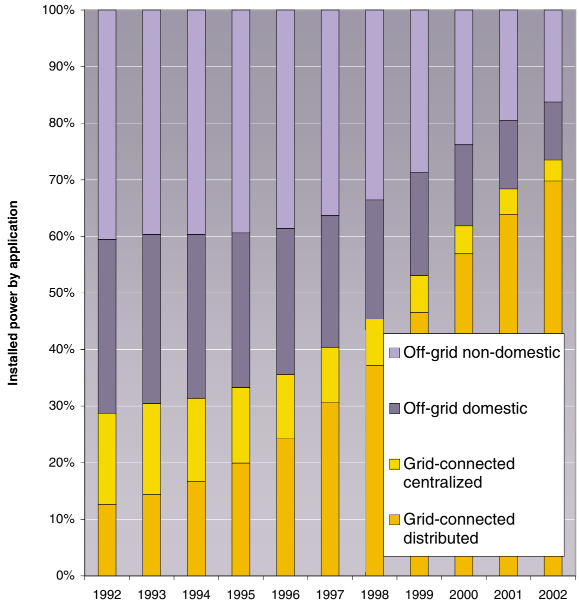


Figure 2 illustrates that since 1999, the majority of PV capacity has been installed in applications that are connected to the grid. However, in over half of the reporting countries this is not the case. Over 80 % of PV capacity in Australia, Canada, Finland, France, Israel, Korea, Mexico, Norway and Sweden is for off-grid applications. In Norway, Finland and Sweden the majority of applications are in the vacation and seasonal sector, whilst in Australia, France and Mexico, PV is used as one of the means to achieve rural electrification. In Canada, Israel and Korea, most systems are for industrial and commercial applications including telecommunications and remote monitoring.

The proportion of capacity that is connected to the grid continues to rise, and reached 74 % in 2002, of which 95 % was for distributed systems. In systems not connected to the grid, approximately 38 % is for domestic applications with the remainder for commercial or public service.

The rates of growth seen in Japan, Germany, the Netherlands and the USA have moderated over previous years, but the capacity installed in 2002 in each of these countries is still a high proportion of the total size of the market - Japan (29 %), Germany (30 %), the Netherlands (22 %) and the USA (21 %). In all cases, high rates of growth continue to be driven by government or utility supported programmes that tend to concentrate on grid-connected PV in the urban environment.

Figure 3 - Installed power by application in the reporting countries in 2002

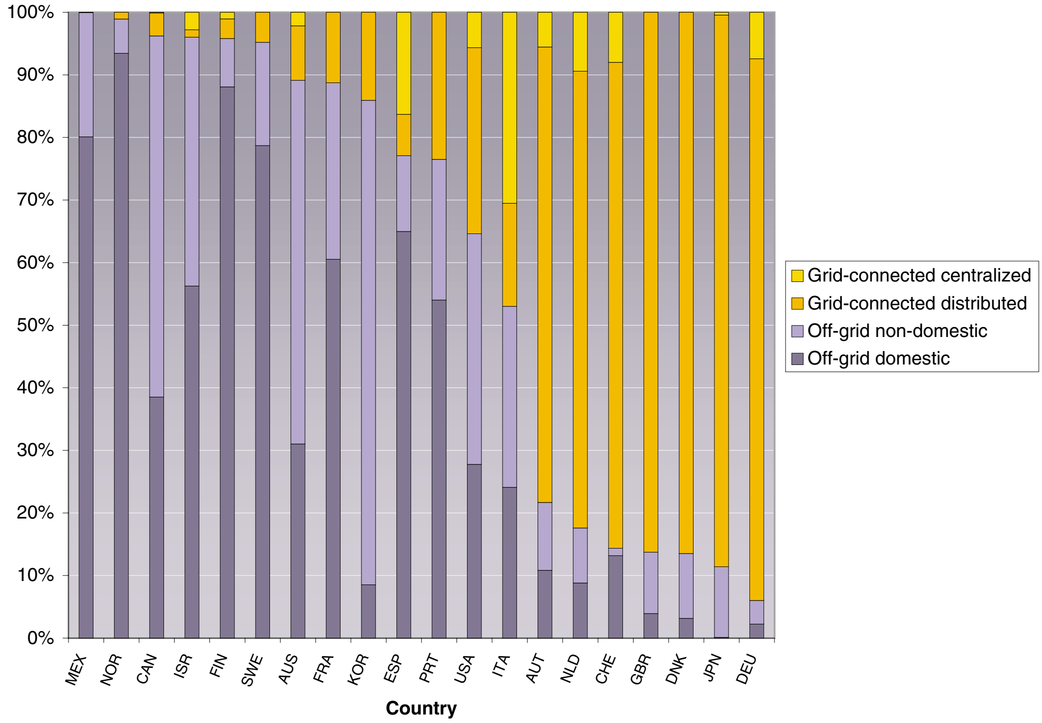


Table 1 – Cumulative installed PV power in reporting countries as of the end of 2002

Country[1]	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 2002 kW	Grid-connected power installed in 2002 kW
AUS	12 140	22 740	3 400	850	**39 130**	1,99	5 550	800
AUT	1 950[2]		6 550	500	**9 000**	1,11	2 462	2 369
CAN	3 854	5 775	368	0	**9 997**	0,32	1 161	26
CHE	2 570[2]	230[2]	15 140	1 560	**19 500**	2,67	1 900	1 800
DNK	50	165	1 375	0	**1 590**	0,29	90	85
DEU	16 700[3]		240 000	20 600	**277 300[4]**	3,37	82 600[4]	82 600
ESP[5]								
FIN	2 688	236	96	32	**3 052**	0,59	322	26
FRA	10 437	4 862	1 942	0	**17 241**	0,29	3 385	970
GBR	162	406	3 568	0	**4 136**	0,07	1 390	1 342
ISR	283	200	6	14	**503**	0,08	30	0
ITA	5 300	6 365	3 620	6 715	**22 000**	0,38	2 000	1 985
JPN	650	71 997	561 295	2 900	**636 842**	5,00	184 029	178 209
KOR	461	4 188	761	0	**5 410**	0,11	653	237
MEX	12 943	3 208	10	0	**16 161**	0,16	1 190	1
NLD	4 632[2]		19 214	2 480	**26 326**	1,64	5 817	5 515
NOR	5 966	350	68	0	**6 384**	1,42	174	3
PRT	901	375	392	0	**1 668**	0,16	358	73
SWE	2 595	544	158	0	**3 297**	0,37	265	9
USA	58 900	78 200	63 100	12 000	**212 200**	0,74	44 400	22 500[6]
Total[7]	**129 400**	**213 623**	**921 063**	**47 651**	**1 311 737**		**337 776**	**298 550**

[1] *ISO country codes are outlined in Table 11.*
[2] *Off-grid domestic and non-domestic data not precisely delineated.*
[3] *Difficult to determine: at least 6 200 kW and 10 500 kW for off-grid domestic and non-domestic respectively.*
[4] *Uncertain due to off-grid data estimate.*
[5] *Data not provided*
[6] *1 000 kW described as 'Government Projects' has been categorized as 50 % off-grid non-domestic, 50 % grid-connected distributed.*
[7] *Conservative 'best estimate' as a consequence of notes 2 – 6 above. Does not include Spain.*

Table 2 - Cumulative installed PV power in IEA-PVPS countries: historical perspective

	Cumulative installed PV power MW										
Country[1]	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
AUS	7,3	8,9	10,7	12,7	15,7	18,7	22,5	25,3	29,2	33,6	39,1
AUT	0,6	0,8	1,1	1,4	1,7	2,2	2,9	3,7	4,9	6,6	9,0
CAN	1,0	1,2	1,5	1,9	2,6	3,4	4,5	5,8	7,2	8,8	10,0
CHE	4,7	5,8	6,7	7,5	8,4	9,7	11,5	13,4	15,3	17,6	19,5
DNK		0,1	0,1	0,1	0,2	0,4	0,5	1,1	1,5	1,5	1,6
DEU	5,6	8,9	12,4	17,8	27,9	41,9	53,9	69,5	113,8	194,7	277,3[2]
ESP	4,0	4,6	5,7	6,5	6,9	7,1	8,0	9,1	9,1[3]	16,0[4]	16,0[5]
FIN	0,9	1,0	1,2	1,3	1,5	2,0	2,2	2,3	2,6	2,7	3,1
FRA	1,8	2,1	2,4	2,9	4,4	6,1	7,6	9,1	11,3	13,9	17,2
GBR	0,2	0,3	0,3	0,4	0,4	0,6	0,7	1,1	1,9	2,7	4,1
ISR	0,1	0,1	0,2	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,5
ITA	8,5	12,1	14,1	15,8	16,0	16,7	17,7	18,5	19,0	20,0	22,0
JPN	19,0	24,3	31,2	43,4	59,6	91,3	133,4	208,6	330,2	452,8	636,8
KOR	1,5	1,6	1,7	1,8	2,1	2,5	3,0	3,5	4,0	4,8	5,4
MEX	5,4	7,1	8,8	9,2	10,0	11,0	12,0	12,9	13,9	15,0	16,2
NLD	1,3	1,6	2,0	2,4	3,3	4,0	6,5	9,2	12,8	20,5	26,3
NOR	3,8	4,1	4,4	4,7	4,9	5,2	5,4	5,7	6,0	6,2	6,4
PRT	0,2	0,2	0,3	0,3	0,4	0,5	0,6	0,9	1,1	1,2	1,7
SWE	0,8	1,0	1,3	1,6	1,8	2,1	2,4	2,6	2,8	3,0	3,3
USA	43,5	50,3	57,8	66,8	76,5	88,2	100,1	117,3	138,8	167,8	212,2
Total[6]	**109,9**	**136,2**	**163,9**	**198,6**	**244,7**	**314,0**	**395,7**	**520,0**	**725,8**	**990,0**	**1 327,7**

1.3 Major projects, demonstration and field test programmes

As in previous years, the majority of projects reported in this section are in the grid-connected sectors, with very few off-grid applications reported. This is due to the continued emphasis on national programmes and support measures directed to the grid-connected sector.

Australia (AUS)

The Photovoltaic Rebate Programme aims to encourage the development of BIPV. Over 950 systems were installed under this programme in 2002, amounting to 1,2 MW of capacity, which was split evenly between grid-connected and off-grid applications. The Remote Renewable Power Generation Programme continued to deliver primarily (but not exclusively) PV applications in remote areas and the New South Wales Solar in Schools Programme has led to 43 'Solar Schools' being established by the end of 2002.

Austria (AUT)

Two main themes run through the projects completed during 2002: optimizing the architectural integration of BIPV projects and PV power plant installations in regions with attractive feed-in tariffs. At Graz, a redundant industrial building was refurbished as an events hall in preparation for the "2003 - Cultural Capital of Europe" festival and included a 35 kW PV system. In the course of rebuilding the Kriegerhorn cable car station, a 9,5 kW PV system was integrated into the glassfaçade using semi-transparent cells and a non-penetrative mounting system. Due to attractive electricity purchase tariffs paid in the state of Salzburg, several PV installations were installed there in 2002. One of the largest in Austria, a 235 kW multicrystalline system is situated on a slope in the community of Werfenweng.

Canada (CAN)

Canada's first demonstration of "community-scale residential PV roof tops" has been initiated in Waterloo, Ontario, with the aim of accelerating the acceptance of PV in the market and developing a framework for expanding the project to other parts of Canada. This project will also study the impact of solar-powered neighbourhoods on the electrical utility, financial institutions, and municipal planning and bylaws.

[1] *ISO country codes are outlined in Table 11.*
[2] *Includes off-grid data estimate*
[3] *Data not provided. Installed power for end 1999*
[4] *Data from* IEA Statistics
[5] *Data from* IEA Statistics *previous year – 2002 information not available*
[6] *Totals reflect conservative 'best estimates' based on the latest information made available to the IEA-PVPS Programme from all countries for previous years, and are updated as required.*

In parallel, the national committee MicroPower Connect (www.micropower-connect.org) has completed the guideline for the interconnection of small distributed generation, and the Alberta Safety Codes Council Task Force on MicroPower and the Canadian Electrical Code has completed an extensive review of the Code and submitted recommendations for changes that will remove the Code's interconnection barriers.

Denmark (DNK)
Uncertainty as to the priorities in Denmark's energy strategy during 2002 resulted in a pause in the growth of PV applications. SOL-1000, the highest profile programme, has been restructured with lower support levels and a lower target capacity of 600 kW, but even so was quickly oversubscribed. Net metering arrangements have been extended to 2006, pending the publication of a national strategy for PV expected during 2003.

Finland (FIN)
The first 24 kW of a 35 kW BIPV project was commissioned at the ecological suburb of Ekovikki during November 2002. However the domestic market continues to be dominated by small solar home systems for vacation cottages that typically range between
50 – 100 W in size. Public support concentrates on R & D activities within research institutions.

France (FRA)
A new five-year programme started in 2002, aiming to install 20 MW of BIPV systems over the period. The programme provides an investment contribution of up to 80 % capital cost, and a subsidized electricity sale price, which is doubled for projects in Corsica or the Overseas Departments. This measure joins the long running FACÉ fund and tax exemption scheme for rural electrification.

Germany (DEU)
Whilst the support measures for grid-connected PV in Germany have remained during 2002, a weak German economy, the introduction of the Euro and political uncertainty have reduced the demand for new systems in 2002. The 'Sun at School' and '300 Parishes for Solar Energy' programmes continued. Two centralized grid-connected projects of 1,75 MW and 4,0 MW were realized in Bavaria with commercial funding. One of the first major applications for CIS modules was commissioned at Marbach in Baden-Wüttemberg with 50 kW of modules installed on the roof of an information centre.

Israel (ISR)
Israel's first toll road opened in 2002, with the cameras used for reading licence numbers for toll collection being powered by PV. A floating laboratory for research at Lake Kineret is powered by a 1,5 kW system that not only powers pumping, refrigeration, testing equipment and lighting but also can provide a limited level of propulsion power. High visibility PV powered equipment include irrigation control and new automats for selling parking tickets in cities.

Italy (ITA)
Over-subscription of the starting phase of the national share of the Italian Roof Top Programme has stimulated further investment by the government, with the expected final capacity rising from 1,8 MW (of which 1,7 MW were installed in 2002) to 5,4 MW. The regional part of the programme, which intends to deliver projects to both public and private buildings, has been slower to start; as a consequence only about 300 kW have already been installed, out of 17,5 MW expected. The Italian Demonstration Programme continues to concentrate on utility scale grid-connected plants.

Japan (JPN)
The seven main research and demonstration projects in Japan continue to deliver very high levels of installations, with 87 % destined for the residential sector, mainly in the range of 3 – 5 kW. Public sector installations in the range 10 – 50 kW account for 2,8 % of installations. Larger installations in the industrial or commercial sectors account for 6,9 %, a proportion that is growing year by year (up from 1,9 % in 2001). Most of these measures provide a direct capital subsidy on the installation cost of the equipment.

Korea (KOR)
Continued support from the Government under the Local Energy Development Project has resulted in a wide variety of PV systems being installed, focusing on grid-connected distributed systems owned by local authorities and public bodies. Examples include a 53 kW roof mounted system at Chosun University and an additional 30 kW to join the 107 kW already installed at the International Cave Exposition site in Gangwon province. In addition, two off-grid PV-diesel hybrid systems with a PV capacity of 60 kW and 23 kW were commissioned in 2002.

Mexico (MEX)
The municipality of San Pedro Garza Garcia implemented 'The Intelligent City Project' that has provided internet kiosks that are partly powered by grid-connected PV. One of the aims of the project was to evaluate grid-connected PV in public buildings and

demonstrate the technology in urban settings. The municipality intends to replicate the project in other cities.

The Netherlands (NLD)
The renovation of 364 dwellings in Apeldoorn by the St Joseph Housing Association provided the opportunity for a large scale solar roof programme. The 1 MW of installed capacity comprises 20 m^2 of modules that cover each roof entirely and in total provide for the electricity needs of the dwellings. The Netherlands can also report the world's first city, Maudurodam, near The Hague, that is entirely powered by PV. The city's total installed capacity of 42 kW is sufficient as it is a theme park that contains a city in miniature!

Norway (NOR)
Activities in the EU financed PV-NORD project, aimed at sharing experience on building integrated PV across the Nordic region, commenced during 2002. Demonstrations will not take place until 2003. The PV market remains dominated by the off-grid market providing power for vacation houses, leisure boats, navigational aids and telecommunications. A small (0,72 kW) BIPV system was installed at a school in Fredrikstad during 2002.

Portugal (PRT)
Whilst new Government legislation increasingly supports grid-connected applications, off-grid projects dominate. An electrification project in the Madeira region delivered four off-grid 1,5 kW PV systems and 2 PV-wind hybrid systems. The main grid-connected projects continue to be installed under BP's petrol station programme, with 5 projects totalling 73 kW capacity installed in 2002.

Sweden (SWE)
During 2002 four major demonstration projects were commissioned. Two (11,4 kW and 3 kW) were part of the Hammarby Sjöstad housing area south of Stockholm, one at Stockholm central station (2,6 kW) and one on the Almedalen Library in Visby (5 kW). Sweden will be participating in PV-NORD, which will result in two further residential related projects that both incorporate solar shading in their designs.

Switzerland (CHE)
The emphasis in programmes continues on novel and innovative PV applications, with monitoring and assessment being a strong theme. An example is on a supermarket roof in Zurich, where the installation of six different types of thin film cells – each with three standard modes of mounting – and a single crystal silicon field as a control, will allow a direct comparison of performance. One of the largest installations is that

Polysilicon Production Plant, Solar Grade Silicon LLC, Moses Lake, WA, USA

at the new terminal of Zurich Airport, where a 283 kW plant demonstrates multifunctional BIPV, which includes shading for passenger lounges.

United Kingdom (GBR)
Three key Government programmes have resulted in half of the 1,4 MW installed in the UK during 2002. The Major Demonstration Programme aims to deliver 3 000 domestic PV systems and 140 larger systems on non-domestic buildings over a three year period. The Domestic PV Field Trial is aiming to tackle technical and institutional barriers. The Large Scale BIPV Field Trial is supporting 18 projects totalling 1,15 MW on public buildings, two of which were installed in 2002. One of these latter projects, at the Alexander Stadium in Birmingham, uses thin film laminates integrated into the roof structure and is currently the largest solar roof in the UK (102 kW over 1 500 m^2).

United States of America (USA)
The Sacramento Municipal Utility District (SMUD) PV Pioneer II programme offers the sale of subsidized grid-connected PV systems to customers. In 2002, SMUD installed 1,4 MW of PV systems and promoted a Solar Advantage Homes programme, where production homebuilders offer commercially built homes with PV systems as a standard feature. The Los Angeles Department of Water and Power (LADWP) operates a 20 MUSD per year incentive programme. The California Emerging Renewables Buy Down Programme provides cash rebates for the installation of new renewable energy generation, including PV, small wind, and fuel cells fuelled with renewable sources. The programme has stimulated over 8 MW of PV system installations in 2002. The Long Island Power Authority operates a significant incentive programme. Other states offer a variety of programmes – a comprehensive summary can be found at www.dsireusa.org.

1.4 Budgets for market stimulation, R&D and demonstration

Countries experiencing rapid growth in the rate of installation of PV capacity continue to be supported by significant public budgets for market stimulation, research and development, and demonstration and field trials. However, the amount of money made available in 2002 in the reporting countries varies widely – from negligible to more than 250 MUSD. Table 3 gives these budgets for 2002 for reporting countries. It should be noted that the boundaries of what constitutes 'research', 'development', 'demonstration / field trials' and 'market stimulation measures' often vary from country to country and are thus not always comparable. However, in most (but not all) cases the total budget showed an increase from the previous year. For many of the countries the increase was dramatic.

Some countries emphasized R&D spending (for example, Austria, Canada, Israel, Norway and Sweden); others focused on market stimulation during 2002 (for example, Australia, Italy and Japan). However, in general, the budget for the demonstration and field trials of PV systems continues to represent a small proportion of the public budgets, with the exception of the United Kingdom and Korea in 2002.

2 The PV Industry

This section provides information on PV cell and module manufacturing in the IEA-PVPS countries during 2002. A regional overview is presented in Table 4, while Table 5 summarizes the information provided in the national survey reports by the participating countries and likely accounts for about 90 % of worldwide production. The data does not include input from countries with significant PV activities like China /Hong Kong, India, Malaysia, Russia, Taiwan and Ukraine since these countries are not parties to the IEA-PVPS Implementing Agreement.

2.1 Photovoltaic cell and module production

The PV business continues to expand rapidly. Total photovoltaic cell production volume for 2002 was reported to be 520 MW, an increase of 51 % from 2001. The cell production capacity grew from 494 MW to 801 MW, an increase of 62 %. Module production and production capacity enjoyed similar strong growth throughout 2002.

Japan produced 47 % of the cells (244 MW) and 54 % of the modules (260 MW) reported. Germany showed an expansion of over 40 % for module production,

Table 3 - Public budget for R&D, demonstration/field trials and market stimulation in 2002

	Annual budget – thousand USD			
Country[1]	**R&D**	**Demonstration/ field trials**	**Market stimulation**	**Total**
AUS	1 195	1 793	8 202	11 190
AUT	1 037	–	–	1 037
CAN	5 223	382	350	5 955
CHE	9 184	1 284	2 762	13 230
DNK	1 903	634	–	2 537
DEU	22 243	[2]	[3]	
FIN	377	–	19	396
FRA	9 237	8 200		17 436
GBR	6 072	5 937	–	12 009
ISR	198	0	0	198
ITA	4 713	0	51 838	56 551
JPN (METI)	59 058	35 914	185 156	280 128
KOR	3 241	5 871	1 767	10 879
MEX	787	11	–	798
NLD	9 107	172	5 862	15 141
NOR	1 120	0	0	1 120
PRT	~	~	–	Data not PV specific
SWE	2 119	201	0	2 320
USA[4]	35 000	0	79 600	114 600

[1] *ISO country codes are outlined in Table 11.*
[2] *Relatively low level; spent by the Federal States on special, innovative projects*
[3] *2002 feed-in support has been estimated at 55 853 (thousand USD); budget for loans is 23 563 (thousand USD).*
[4] *FY2003 (Oct 2002 – Sept 2003)*

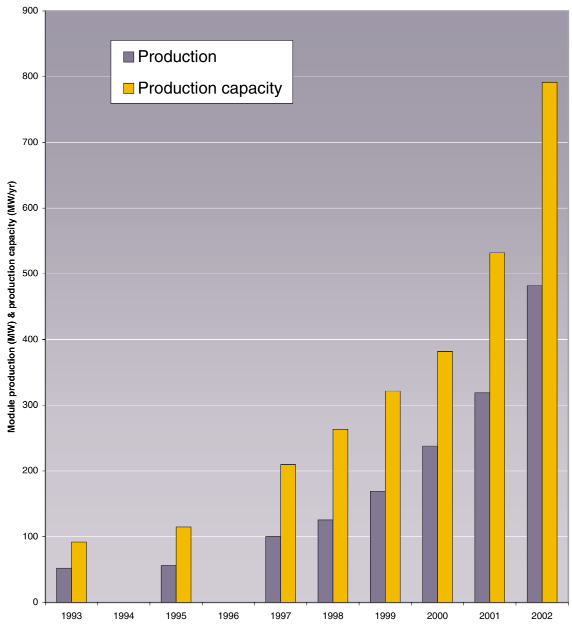
to account for 8,5 % of the total reported market. Interestingly the German production is reported to account for less than half of the local demand in 2002. The United States is still a large producer of PV cells (121 MW) but their expansion is not as rapid as in the other countries.

Several interesting trends for the activities in the photovoltaic industry value chain can be identified.

Crystalline silicon is defending its place as the world leading technology for photovoltaic cells, with more than 80 % of the modules shipped in 2002 being either single crystal or multicrystalline silicon.

The silicon feedstock supply managed to keep up with the growth in demand. Traditional polysilicon producers had overcapacity in 2001 and 2002, and no shortage of polysilicon is again expected in 2003. However, if the electronics industry should experience the growth expected, there may be bottlenecks in cheap silicon feedstock supply in the period 2004 to 2005.

Figure 4 - PV module production and module production capacity between 1993 and 2002 in IEA-PVPS countries



In 2002, the Renewable Energy Corporation AS (Norway) and ASiMI LLC (USA) entered into a joint venture called Solar Grade Silicon LLC (SGS). The aim of the joint venture is to immediately produce 2 000 t of photovoltaic grade polysilicon and to further develop low cost granular polysilicon feedstock for the PV business. Production is located at SGS's plant at Moses Lake, USA. Through this move, REC has become the first solar energy company with its own feedstock production. There are other plans to start production of PV grade silicon. Elkem, a world-wide leading supplier of metallurgical grade silicon, has long researched such processes, and expects to start commercial production within the next few years. Deutsche Solar and Wacker Chemie (Germany) also have plans to take up PV grade silicon production. Topsil (a Danish producer of float-zone silicon for the semiconductor industry) announced its intention to supply the international PV industry with high purity, low cost silicon.

The production capacity for wafers has increased significantly during the last year. In the UK, Crystalox continued its strong growth by increasing its output of multicrystalline silicon ingots by 250 % as compared with 2001. The growth from 2000 to 2001 was 200%. The company's total ingot production for 2002 was sufficient for 75 MW of cell production and was exported primarily to Japan and Germany. In Germany, PV Crystalox Solar produces wafers from the ingots.

In Germany there are two other important wafer producers, Deutsche Solar and RWE Schott Solar (however, at present, RWE Schott Solar is producing EFG ribbon wafers only in the US). Both these companies are aiming at fully integrated production of crystalline silicon PV modules, performing all major production steps in-house. The total wafer production capacity in Germany was reported to be 87 MW in 2002. Both Deutsche Solar and RWE Schott Solar have ambitious plans for expanding capacity. The former expects to expand from 32 to 100 MW during 2003, and the latter is installing a 10 MW EFG ribbon wafer plant. In Japan, Kawasaki Steel started

Table 4 - PV cell and module production (MW) in 2002 by world region in IEA-PVPS countries

	Cell Production All types	Cell Production Capacity	Module Production						Module Production Capacity
			sc-Si	mc-Si*	a-Si	Undefined**	Other**	Total	
Japan	244	361	39	186	5	30		260	405
USA	121	177	45	20	11	1	4	81	148
Europe	134	226	74	34	4	19	2	133	217
Rest	21	37	3	4			1	8	22
TOTAL	**520**	**801**	**161**	**244**	**20**	**50**	**7**	**482**	**792**

** includes modules based on EFG and String Ribbon cells*
*** 'undefined' means the technology type was not clarified; 'other' refers to technologies other than silicon based*

silicon ingot production in 2001 and Metal Reclaim is planning to manufacture wafers from 2003. ScanWafer AS in Norway has become a significant supplier of multicrystalline silicon wafers. Since the start of production in 1997 the output has been continuously increased, and the nominal capacity (calculated on the basis of wafers converted to 13,5 % efficiency cells) has now reached 55 MW. The capacity is expected to reach 80 MW by the end of 2003 and 140 MW by the end of 2004. Eurosolare (Italy) has a joint venture with China for wafer production.

As mentioned above, cell production continued to grow strongly in 2002. However, the German 100 000 roofs programme may not be continued in its present form in 2004, and the legislative framework supporting renewable energy will be revised. This is leading to uncertainty about the future among producers both within and outside of Germany. Capacity expansion plans in Germany and the USA have therefore been revised. The picture regarding cell and module capacity expansions is not clear. Some lines closed in 2002, but new capacity was also installed. Capacity, especially for module production, is shifting to low cost labour countries. Nevertheless, RWE is currently building an integrated cell and module plant with 60 MW capacity, while Deutsche Cell has installed new production capacity for 22 MW of cells. Gällivare Photovoltaics in Sweden will increase capacity to 20 MW, and the German company Solar Factory plans to install 15 MW of new module production capacity in 2003. Both are subsidiaries of German SolarWorld. There are also new cell and module producers starting in countries like Austria, Norway and Sweden.

Although crystalline silicon increased its market share in 2002, the thin film industry contributed several interesting developments. Pacific Solar in Australia continues to develop its polycrystalline thin film product, and STI in the same country produces dye sensitized cells (TiO_2). In Japan a new plant for a-Si was opened and a 13,52 % efficiency copper-indium-diselenide (CIS) module (3 459 cm^2) was developed. In Germany, no less than three thin-film producers started in 2002, producing CdTe cells as well as a-Si and CIS cells. In Japan, the research activity on thin-film technology is particularly significant, reflecting the high priority placed on PV technology. On the other hand, several production facilities for thin-film modules were shut down in 2002 or shortly afterwards. Significantly, AnTech, BP Solar and Matsushita Battery all closed down their CdTe production. This development may reflect a market not embracing the raw materials of this technology.

The new spheral PV technology continues to move forward in Canada, with Automation Tooling Systems commercializing its flexible, low-cost spheral technology (which consists of thousands of 0,75 mm silicon beads in an aluminium foil) and building a 20 MW per year plant.

The major PV cell and module manufacturers in the different countries are summarized in Table 5. For conventional crystalline silicon PV technology, cell and module manufacture are separate processes, mostly carried out by different production units, although the major producers control all steps within their own business. Thin-film technologies are normally integrated processes where cells and modules are produced in the same production line. Companies working with these technologies therefore tend to be integrated cell and module manufacturers.

Table 5 - PV product manufacturers in reporting countries

Country (% export: cells/ modules)	**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 (63 / 20)	BP Solar	sc-Si	7	3	10	4
		mc-Si	13	4	20	8
	STI	Titania Dye	0,5	0,5	0,5	0,5
	Solar Systems	Concentrator	0,2	2	5	5
AUT	PVT Austria	mc-Si		N/A		N/A
CAN	ICP Global	sc-Si, mc-Si		0,5		2
CHE	Swiss Sustainable Systems	sc-Si, mc-Si		0,25		1
	Star Unity	mc-Si		0,02		0,1
	SES	sc-Si				2
	Solterra SA	sc-Si				N/A
	VHF Technologies	a-Si				0,06
DNK	Gaia Solar	mc-Si, sc-Si		0,1		0,33

Table 5 - continued

Country (% export: cells/ modules)	Company	Technology Type	Total Production		Maximum Production Capacity	
			Cell MW per year	**Module** MW per year	**Cell** MW per year	**Module** MW per year
DEU	Solar Fabrik GmbH	sc-Si		7,2		7,92
	SOLON AG, Berlin	misc. sc-Si		6		6,6
		and mc-Si				
	Shell Solar GmbH	Sc-Si	9	5	10	5,5
	Solarwatt Solar-Systeme GmbH	misc. sc-Si		4		4,4
		and mc-Si				
	Solara AG	mc-Si		3		3,3
	Alfasolar Vertriebsgesellschaft GmbH			2,5		2,75
	Flabeg Solar*	Sc-Si, mc-Si		2,5	8	2,75
	GSS GmbH and IPEG GmbH	mc-Si		2,5		2,75
	S.M.D. Solar-Manufaktur Deutschland GmbH			1,5		1,65
	AnTec Solar GmbH*	Cd-Te		1,5		10
	RWE Schott Solar GmbH	a-Si		1		1
	Saint Gobain Glass Solar GmbH	mc-Si		1		1,1
	Solarnova GmbH	sc-Si, mc-Si		1		1,1
	Webasto Systemkomp. GmbH	Sc-Si		1		1,1
	RWE Solar GmbH	EFG, mc-Si	25	0,5	43	0,55
	Würth Solar GmbH	CIS		0,15		0,35
	Q-Cells AG	mc-Si	9		24	
	Ersol Solar Energy GmbH	mc-Si	9		10	
	Sunways A.G.	mc-Si	5		7	
	Others (5 companies)			1,522		1,6742
ESP****	Isofoton	sc-Si	27,4	21,6	36	36
	BP Solar Espana	sc-Si	16,5	16,7	16,5	25
	Atersa	sc-Si	6,5	8,3	18	23
		mc-Si	0,5	0,7	2	2
FRA	Photowatt International	mc-Si	17	8	25	10
	Free Energy Europe	a-Si	0,5	0,5	1	1
GBR (70/70)	Intersolar	a-Si	2,3	2,3	3	3
ITA	Helios Technology	sc-Si	2,9	2,9	4,5	4,5
	Eurosolare	sc-Si	0,2	0,2	8,5	8,5
		mc-Si	2	2		
JPN	Sharp	sc-Si	22,56	13,95	200	200
		mc-Si	100,5	93,59		
		a-Si	0,01	0,01		
	Kyocera	mc-Si	62	60	70	70
	MSK	mc-Si		8		10
		sc-Si		23		25
		a-Si		0,5		3
	Sanyo Electric	a-Si/sc-Si	26	26	30	30
	Mitsubishi Electric	mc-Si	24	24	26	26
	Kaneka	a-Si	4	4	10	10
		a-Si/poly-Si	3,5	3,5	10	10
	Showa Shell Sekiyu	sc-Si		1,2		6
	Matsushita Ecology Systems	sc-Si	1	1	3	3
	Canon	a-Si/micro-	0,72	0,72	10	10
		crystalline-Si				
	Mitsubishi Heavy Industries	a-Si	0,1	0,1	2	2
KOR	S-Energy Co	mc-Si		0,35		0,5
	LG Industrial System	sc-Si		0,25		0,5
	Haesung Solar	sc-Si		0,1		0,5
	Solar Tech	sc-Si, mc-Si		0,075		0,5
	Photon Semiconductor & Energy	sc-Si	0,18		0,5	
	Neskor Solar	sc-Si	0,12		0,7	

Table 5 - continued

Country (% export: cells/ modules)	Company	Technology Type	Total Production		Maximum Production Capacity	
			Cell MW per year	**Module** MW per year	**Cell** MW per year	**Module** MW per year
NLD	Shell Solar Energy	mc-Si	0,9	7,3	4	10
	Philips Solar Energy**	sc-Si, mc-Si, a-Si				
	Logic Electronics**					
	AKZO Nobel***					
NOR	ScanCell	mc-Si	0,01		7	
PRT	Shell Solar	sc-Si		10,8		15
SWE (n.a./>93)	GPV	mc-Si		6		15
	Artic Solar	mc-Si		3		6
USA	Shell Solar	sc-Si	43,5	30	45	40
		CIS	3	3	3	3
	BP Solar	mc-Si	24	15	24	20
		a-Si	7	7	9	9
		Cd-Te*	0,3	0,3		
	AstroPower	sc-Si	28	15	40	20
		Si film	1,7	1	2	2
	RWE Schott (ASE)	EFG-Si	5	5	10	10
	United Solar Systems (USSC)	a-Si	4	4	30	30
	Evergreen Solar	String ribbon	1,9	0,4	4	4
	Other		2,5	0,5	10	10

Notes

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

** ceased production during 2002*
*** started production in 2002 – data not yet available*
**** planning production – still in R&D stage*
***** data source – ASIF (Spain)*

Another feature of the past year was the significant number of companies in different countries that put PV products for building (including roof) integration on the market. These products rely on both crystalline silicon and thin film technologies. While the markets for such products are still relatively limited, the number of products available clearly indicates that producers believe this will become an important market segment.

2.2 Balance of system component manufacturers and suppliers

A large industry exists that supplies balance of system components such as inverters, batteries, battery charge controllers, switchgear and cabling. The producers of this equipment are usually general producers of electronic equipment and batteries. Interesting developments in recent years have been the development of charge controllers capable of communication over mobile telephone (GSM) networks and an increased line of inverters for grid-connection of PV. As in the cell and module production business, there is a strong focus on cost reduction through innovative designs that reduce investment costs and installation and maintenance work.

2.3 System prices

Prices for entire PV systems vary widely and depend on a variety of factors including system size, location, customer type, grid-connection, technical specification and, of course, the extent to which end-user prices reflect the real costs of all the components. For more detailed information, the reader is directed to each country's national survey report.

System prices for off-grid applications tend to be greater than those for grid-connected applications, as the latter do not require storage 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. Although there is considerable variation in the data, off-grid system prices are about twice the price of grid-connected systems in each of the countries. For BIPV systems the price will vary significantly depending on whether the system is part of a retrofit or is integrated into a new building structure. Market stimulation measures can have dramatic effects on demand (and thus supply) of equipment in the target sector. The cost and complexity of permits and grid-connection controls can also impose significant costs, especially for smaller systems.

PV modules comprise a significant proportion of system prices (on average, about 60 % for grid-connected systems in 2002) and, compared to the widely-varying non-technical and other costs, presents a useful indicator for tracking the changes in PV technology costs over time. The average price of modules in 2002 in the reporting countries is 4,1 USD per watt, with indications that the current lowest achieved prices of modules are less than 3 USD per watt. Table 6 shows the change in module (current) prices in some of the reporting countries from year to year. In 2002 prices generally decreased from the previous year, ranging from no change to falls of about 20 %. Although presented as current prices, it is interesting to compare the results with those suggested by 'technology learning curves' (which suggest a cost decrease of 15 – 20 % for a doubling of market size). Table 2 shows a doubling of market size in the reporting countries of a little more than every two years in recent years. Table 6 indicates that, for larger markets, module (current) prices are now falling between 10 and 17 % per doubling of market size, although the trend may not be smooth. This is also shown for current prices in Figure 5.

In 2002, system prices in the off-grid sector up to 1 kW varied considerably (Table 7), typically from about 10 to 18 USD per watt. The large range of reported prices is likely to be a function of the country and project specific factors. Off-grid systems greater than 1 kW tend to show slightly less variation and generally slightly lower prices.

The installed price of grid-connected systems in 2002 also varied (but not as widely as off-grid prices) both within and between countries, as shown in Table 7. The lowest reported prices were close to 4 USD per watt and were achieved in special circumstances (see national survey reports); prices of 5 to 5,5 USD per watt were not uncommon but 7 USD per watt is a more typical price. The cost structure of the system price can vary dramatically between countries (and between projects). For example, in 2002 the cost of modules made up anywhere from 50 – 80 % of the reported grid-connected system prices. Larger installations may have lower or higher system prices, depending on the degree of building integration, installation difficulty and innovation.

Figure 5 – PV system price trends in selected reporting countries

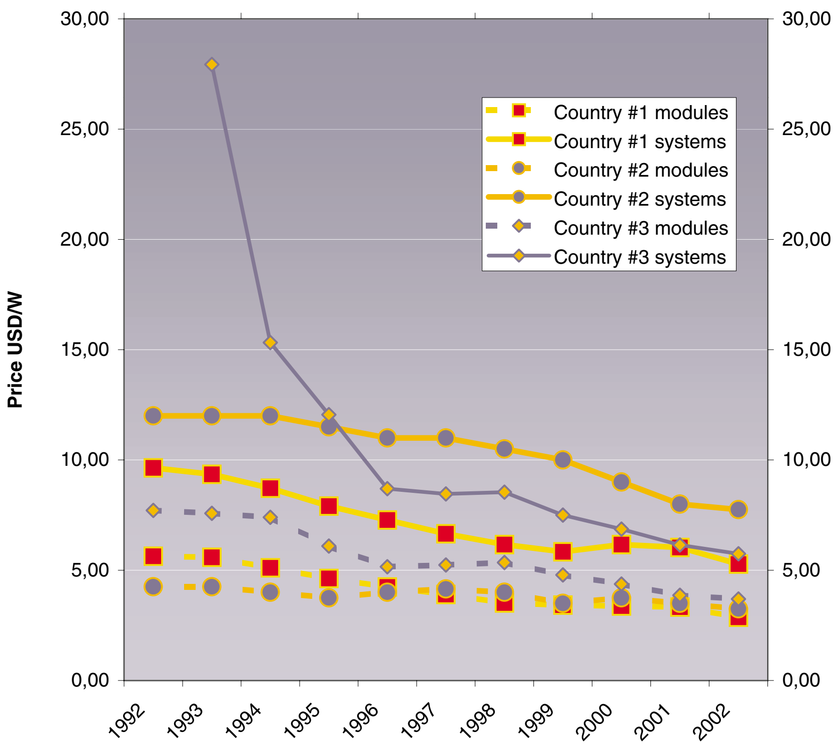


Figure 5 shows a continuing downward trend in grid-connected system prices in selected countries and the associated less-variable downward trend for the module prices. The convergence of prices in the different countries continues, indicating the worldwide trading of modules and the attention to some of the non-technical barriers.

Table 6 - Indicative module prices[1] in national currencies per watt in selected countries

Country[2]	Currency[3]	1992	1993	1994	1996	1997	1998	1999	2000	2001	2002	2002 USD	Best price[4] 2002
AUS	**AUD**			7	8			8	8	8	7	**3,8**	6,5
AUT	**EUR**										4,5	**4,2**	
CAN	**CAD**							11,09	10,7	9,41	7,14	**4,5**	
CHE	**CHF**										7,5	**4,8**	
DNK	**DKK**								40	40	33	**4,2**	21
DEU	**EUR**	5,98	5,93	5,42	4,50	4,14	3,73	3,63	3,58	3,53	3,04	**2,9**	
GBR	**GBP**									3,7	3,7	**5,5**	2,7
ITA	**EUR**		4,65			4,13			4,13	4,25	3,9	**3,7**	3,5
JPN	**JPY**	966	950	927	646	656	670	600	548	484	463	**3,7**	
KOR	**KRW**			9 400	8 200	8 500	9 200	7 500	7 100	7 200	7 200	**5,8**	6 500
NLD	**EUR**			9,5	7,5	6	5	4,75	4,73	4,73	4,62	**4,4**	
NOR	**USD**										**3,3 (imports)**		
PRT	**EUR**									4	3,5	**3,3**	
USA	**USD**	4,25	4,25	4,00	4,00	4,15	4,00	3,50	3,75	3,50	**3,25**		2,75
Average (non-weighted)												**4,1**	

[1] *Current prices*
[2] *ISO country codes are outlined in Table 11.*
[3] *ISO currency codes are outlined in Table 11.*
[4] *Best price refers to any special deals that may have been achieved and reported.*

Table 7 - Indicative installed system prices[1] in USD in selected countries in 2002

Country[2]	Off-grid (USD per W)		Grid-connected (USD per W)	
	<1 kW	**>1 kW**	**<10 kW**	**>10 kW**
AUS	10,9 – 12,5	7,1 – 10,9	6,5 – 8,1	5,4 – 7,1
AUT			5,7 – 7,5	5,2 – 7,1
CHE	12,8 – 19,3	9,6 – 16,1	6,1 – 8,3	5,5 – 6,7
DNK	8,9 – 11,4	19 – 25,4	4,3[3] – 5,1	5,1 – 12,7
DEU			5,3	
FIN	11,3 – 17,9		6,6 – 10,4	8,5 – 10,4
FRA	9,4 – 21,7	13,2 – 14,1	7,1	
GBR[4]	8,1 – 15	7,8 – 13,5	6,4 – 22,2	6,4 – 19
ISR			10 – 15	
ITA	12,7	12,3	7,1 – 13,2	6,6
JPN			5,7	6,8
KOR	17,8	17,0	11,7	11,0
MEX	11,4 – 16,6			
NLD[5]	5,4	4,7	5,7 – 5,8	5,4
NOR	6,9 – 18,8			
PRT	11,3	9,4	6,1	
SWE	17			
USA	12 – 25	12 – 20	7 – 10[6]	6,5 – 9

[1] *Additional information about the systems and prices reported for most countries can be found in the various national survey reports on the IEA-PVPS website.*
[2] *ISO country codes are outlined in Table 11.*
[3] *Prices for the new SOL 1000 project*
[4] *More expensive grid-connected system prices are associated with roof integrated slates or tiles, or one-off building integrated designs.*
[5] *Average prices*
[6] *Installed system prices as low as 4 USD/W have been reported & offerings to customers as low as $3,50 USD/W.*

2.4 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 2002. Most countries show an increase in labour places from the previous year. The increase is particularly high in countries establishing a manufacturing base and / or promoting market deployment. There is some concern that sudden changes in market deployment programmes could have negative effects on the employment situation.

Any change in the relative industrial emphasis on different PV technologies reinforces the need to rethink public support policies, in order to focus more directly on those technologies holding promise for achieving cost reductions in the long-term to levels of competing power options. While there is the political need to demonstrate that public expenditure is delivering such outcomes, the willingness to pay of end-users and investors is also an important factor. Social awareness, from issues of personal value systems through to education and sustainability in decision making are strong allies of PV deployment.

3 Framework for Deployment

Local, national and international policies, as well as availability of suitable standards and codes and the perception of the general public and utilities, govern the rate of deployment of PV systems.

3.1 New initiatives in photovoltaic power systems

The research and development support, and funding of demonstration programmes, aim to result in the substantial lowering of PV costs towards what is required for penetration into the general power supply sector. Table 9 highlights the key initiatives reported in the participating countries during 2002.

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 (although it is uncommon to see PV specifically promoted). While public opinion appears to be generally supportive of PV, with a growing level of awareness and access to information reported in many countries, the added values of grid-connected PV – electricity network, architectural, environmental and socio / economic benefits – are yet to be incorporated in most energy policies and programmes. In most of the reporting countries PV is only in the early stages of promoting its portfolio of benefits (with builders, developers, financiers, planners and so on) to create more natural working relationships.

Table 8 - PV industry employment in some countries

Country[1]	R&D[2] persons[3]	Manufacturing[4] persons	Other[5] personnel	Total personnel
AUS	50	350	450	850
AUT				350 – 500
CAN	40	335	160	535
CHE	140	20	330	490
DNK	8	12	10	30
DEU	?	3 200	3 200	>7 000
FIN	15	20	50	85
FRA	75	340	165	580
GBR	67	173	155	395
ISR	85	0	N/A	>85
ITA	100	70	350	520
JPN	300	2 500	7 000	9 800
KOR	47	103	35	185
NLD	150	320	200	670
NOR	20	240	15	275
PRT	29	90	47	166
SWE	25	55	15	95
USA	31	954	116	1 101

[1] *ISO country codes are outlined in Table 11.*
[2] *Research and development (not including companies)*
[3] *Or person-years*
[4] *Manufacturing of PV system components (including company R&D)*
[5] *Including energy companies, distribution, installation and maintenance companies*

Table 9 - Initiatives and perceptions

	New promotional activities	Utility and public perceptions
AUS	Two key national programmes are supporting projects in the off-grid and grid-connected markets. The PV Rebate programme is supporting the development of BIPV, and the Remote Renewable Power Generation Programme aims to reduce the reliance of isolated communities on diesel fuelled generation. The Australian PV industry is launching a roadmap of initiatives and activities required to support the next decade of development.	Utilities offer a range of tariff structures and net metering arrangements to suit PV, but generally the familiarity and support for grid-connection is low, leading to high costs and unnecessary delays in connection procedures. Electricity consumers that are not connected to the grid view PV as an increasingly important and cost effective option, and high profile landmark commercial installations are raising awareness amongst architects and specifiers.
AUT	Legislation to harmonize regulation of renewable energy support was adopted in 2002 that not only sets a national scale of sales tariffs, but also allows network operators to pass on these costs to all customers. However, a maximum of 15 MW of PV capacity is allowed under these measures, and this target is expected to be reached during 2003.	Utilities offer standardized contracts for small generators (< 50 kW), which allow for simple and cost effective grid access for PV. The public perception of PV is excellent, as demonstrated by the high levels of interest in the new legislation and strong support for PV to be included in green electricity bearing the Austrian ecolabel ”Unweltzeichen”.
CAN	Within the framework to reduce greenhouse gas emissions, a number of programmes are funding PV development and demonstration projects. These include innovation, community and infrastructure related activities.	There are some offerings for green electricity, but government regulations and utility attitudes hinder or do not allow net metering. Approximately six utility companies now have experience with grid-connected PV systems. Applications for grid-connection are still considered on a case-by-case basis, although efforts are underway to reduce the interconnection barriers.
CHE	No national promotional activities are reported, leaving the promotion of PV to companies marketing green electricity. Green power markets have been the driver for growth over the last few years, but it has been reported that there is evidence of saturation in this niche market.	New measures to liberalize the electricity market that would have supported PV were turned down in 2002, and thus direct measures to support all renewable energies are not expected until at least 2005. Public perceptions of renewable energy are still positive, with green electricity products growing much faster than the electricity market.
DNK	When the SOL-1000 programme eventually started during 2002, it did so with lower support levels and targets. Even so, it has been over-subscribed. Standards to allow the connection of DIY kits for PV installations are in preparation. Architects were the focus of awareness raising activities in 2002.	Utilities show an increasing level of support for PV as a potential business area, with interest shown in developing new models of ownership and financing DIY kits and other systems. Public interest and support remain high, and it is expected that the DIY kits can be sold successfully with no incentives beyond net metering.
DEU	The 100 000 roof tops programme will reach its 300 MW cap in 2003. However, the limit for PV support under the Renewable Energy Law during 2002 was raised from 350 MW to 1 000 MW, greatly aiding the planning of future investments in the sector. However the first of the annual 5 % reduction in sales tariffs was felt in 2002, leading to real challenges within the industry to cut costs.	Connection arrangements are routine and a high proportion of utility companies are participating in a large number of PV applications. Public perceptions are focused by the increasing level of environment tax levied on all energy supplies (including PV) to encourage energy saving and low impact product development.
FIN	As part of the Government’s National Climate Strategy, an Action Plan for Renewable Energy launched in 2001 aims to place more emphasis on market support for PV. This theme is taken up by a project started in 2002 to develop the Solar ESCO (energy service company) concept in Finland with the aim of bringing investment into PV development in innovative ways.	Whilst the main public perception of PV is for off-grid power supplies for vacation cottages, initiatives in housing and institutional buildings are bringing new interest forward. Utilities have little practical experience of grid-connection issues.
FRA	A new BIPV programme joined the long running support available for off-grid applications and EU demonstration projects in 2002. The programme, which aims for the installation of 20 MW in France and its Overseas Dèpartements, is supported by capital grants and a fixed buy-back tariff structure.	EDF, the main French electricity utility, has been active in the development of publicly funded off-grid systems, and owns and manages over 5 000 installations. It has also been active in the development of standards for PV and has developed technical and contractual regulations for grid-connected PV.

Table 9 - continued

	New promotional activities	Utility and public perceptions
GBR	Marketing for the new Major Demonstration Programme (MDP) is being carried out by a contractor to the UK Government, mainly via a website and presentations. An EU ALTENER project (PV-DOMSYS) commenced in 2002 and is specifically designed to encourage the take up of PV on domestic dwellings, through marketing campaigns, installer training, education and financial tools.	Nearly all of the 13 network operators in the UK now have experience of grid-connected PV, and are involved in initiatives to agree and implement connection codes. Since the announcement of the MDP, installers and utilities have received an increase in enquiry traffic, and the high political profile of PV has raised the industry's profile.
ISR	The Government passed a resolution in 2002 to set target dates for minimum renewable energy production, relatively modest (2 % by 2007, 5 % by 2016) and not technology specific – but encouraging to the public. Following attendance at the Johannesburg summit in 2002 by key governmental figures, recommendations have been made to reinforce the profile of energy on the environmental agenda.	The overall public image of PV is positive, though the market remains small due to difficult economic conditions. In 2002, there was little progress in providing mechanisms for allowing the grid-connection of PV.
ITA	Additional funds have been made available to finance a second phase of the roof top programme. This will bring the total national and regional projects to be supported to around 23 MW of capacity. Feed-in connection procedures are also expected to be made simpler and less bureaucratic.	ENEL (the largest Italian utility) has actively participated in overcoming technical barriers including grid interface devices, connection requirements and plant maintenance issues, and has established a renewable energy trading company. The roof top programme has raised the profile of PV in line with increasing environmental awareness in the country.
JPN	Whilst there were no new government initiatives started during 2002, existing programmes are still very active. The Japan Photovoltaic Energy Association (JPEA) has published its 30-year vision and roadmap for a rapidly increasing PV market.	Net metering and grid-connection of PV is routine in Japan. Since 2000, the "Green Power Fund" of the electric power industry has grown and is funding PV in several public buildings, schools and hospitals. Both utilities and the general public have a good knowledge and a positive attitude towards PV, reinforced by a substantial number of educational programmes.
KOR	The Solar Land 2010 programme was launched in 2002, which aims to accelerate research, development and demonstration of PV and deliver 30 000 roof top systems of 3 kW capacity by 2010. It is supported by a buy-back arrangement for systems greater than 3 kW and generous electricity sales tariffs.	KEPCO, the state electricity utility is under restructuring as it moves into the private sector. However it maintains a keen interest in PV applications and has direct construction experience. During the year, a number of conferences, exhibitions and other events (including a design competition) raised the profile of PV.
MEX	The majority of projects are directed at off-grid applications where PV is one strand in anti-poverty strategy and an aid to agricultural development. There are no specific promotional activities.	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	Whilst no new large scale programmes started in 2002, many existing schemes continue to deliver projects. NOVEM has commenced a training programme to support installation companies in order to tackle skill shortages in this area. A number of novel financing and support services have been launched in 2002, with one offering a one-stop-shop for design, installation, subsidy applications, financing, guarantees and maintenance of larger household systems.	Whilst public have a high level of product knowledge of the benefits of PV and a positive image, concerns about the economic environment have lead to reservations in investing. Demonstration projects – such as the planned 500 kW system at the Rotterdam Zoo – continue to raise the public profile and educate on the role of PV. Utilities consider connection of PV routine.
NOR	There are no formal promotional activities or programmes in Norway, and demonstration projects tend to be initiated by research or specific private interest. A newly established public company Enova has been charged with delivering the Government targets for renewable energy production, but is currently unlikely to be able to provide specific support to PV.	Utilities have little knowledge of the grid-connection of PV, although some have made selected investments for providing electricity to remote dwellings. The main market is for PV installations for vacation cottages, but this market is only growing slowly.

Table 9 - continued

	New promotional activities	Utility and public perceptions
PRT	A set of initiatives has been introduced aimed at market stimulation in the energy sector, addressing access arrangements for independent power producers, including small PV, and providing greatly enhanced buy-back tariffs. Off-grid applications are supported by direct capital grants of up to 40 % in the private sector and 100 % for public investments.	The lack of grid-connection standards and codes and utility concerns as to the impact of distributed generation on network stability and safety is proving a barrier to wide scale implementation. There is also a lack of building codes permitting the installation of BIPV.
SWE	There are no promotional activities for PV, except for special cases of demonstration projects or in some rural areas where PV is supporting employment opportunities.	Utility companies are generally supportive of PV, and have participated in various demonstration projects through a collaborative R & D company. Whilst the technology is supported in principal by the public, the general perception that the technology is not suited to the climatic zone remains.
USA	The Californian PV subsidy programmes (California Energy Commission residential buydown and California Public Utilities Commission's programme for systems of 30 kW or more) continue to deliver substantial growth in PV applications, as do the SMUD and LADWP municipal programmes. Initiatives in other states are also growing, with over 1 MW installed in Illinois in 2002 and programmes in operation in many states including Ohio, Oregon, New Jersey, New York, Virginia and North Carolina - mainly based on direct investment subsidies.	The federal government is driving forward a policy of deregulation in the electricity industry, which is leading to several positive benefits for PV. However, each state has taken a different route, and thus many different approaches and requirements are evident. Generally utilities are not familiar with grid-connection of PV, except in California where procedures are routine. There are few national policies on global warming, and as such the role of PV is not widely appreciated by the general public.

3.2 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 global climate change negotiations and market reforms of the electricity industries.

Governments are now increasingly relying on the approach commonly referred to as the 'renewable portfolio standard' (RPS) to increase renewable energy deployment in their countries – often, but not solely, as a mandated mechanism for pursuing greenhouse gas emission reductions in addition to fiscal measures. Other reported measures to promote renewables include disclosure on electricity bills, tradable certificates, and branding and labels. In the absence of a national strategy for PV or at least some concrete targets for installed capacity of PV, the RPS and other measures are unlikely to have a positive impact on PV deployment and may even have unforeseen negative implications. This arises because, for example, the RPS requirement for renewable energy may encourage the lowest direct cost renewable energy options (and not PV) for consideration by the liable parties (commonly the electricity retailing businesses) so as to minimize electricity retail price rises. However, there are exceptions – the Swiss renewable electricity label scheme (www.naturemade.org) specifically mentions PV, and the RPS in certain US states (for example, New Jersey, Nevada and Arizona) have specific PV requirements or allowances.

Electricity supply industry reforms are creating environments worldwide that are open to energy services approaches and distributed generation opportunities from the customers' perspective. Utility support for PV remains mixed, although 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. Also the deployment of PV to avoid the costs of grid extensions in remote areas or to reduce the effects of demand peaks in hot weather are attracting some attention.

As noted earlier, a range of 'green power' schemes are being offered by electricity businesses, in which customers can purchase green electricity. In principle, these rely on part of the customer base giving some environmental or other value to renewable energy and paying a premium for the privilege. These also rely on the customer base having trust in the supply of their green electricity and, ideally, an understanding of what makes up their electricity supply. However, green power schemes (especially in their infancy) are often characterized by the same broad, least-cost approach that can be seen in most government-driven

RPS approaches. This does not take into account the potential longer-term competitiveness of technologies such as PV, which may only be realized by specific support in the near-term.

3.3 Standards and codes

The importance of standards and codes for 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 standards for "systems of photovoltaic conversion of solar energy into electrical energy and for all the elements in the entire photovoltaic energy system." Up to 2003 IEC TC82 had published 26 international standards.

Twenty-two countries are participating in TC82, as well as 11 countries that have observer status. Currently, IEC standards development under TC82 is ongoing in six active working groups: glossary, modules, systems, certification, balance-of-system components and concentrators. Since there are common areas of interest between TC82 and other technical committees, there are joint working groups for Batteries (TC21 - batteries / TC82) and Conformity Assessment Schemes (CAB / TC82) as well as a Joint Coordination Group - Distributed Renewable Energy, involving experts from TC82/ TC21 / TC88 (wind turbines) / TC105 (fuel cells). The range of the TC82 work is wide and recently approved new work includes:

- Crystalline silicon PV modules – blank detail specification (draft IEC 62145)
- Performance testing and energy rating of terrestrial PV modules (draft IEC 61853).

During 2002, IEC TC64 – Electrical installations of buildings – published IEC 60364-7-712 which applies to the electrical installation of PV systems, including those involving AC modules.

On a European level, CENELEC is elaborating standards and codes for PV. Recent new work initiatives of CENELEC cover:

- Requirements for grid-connection of PV systems
- Inverter systems for PV systems, grid and stand-alone
- Building integrated solar PV
- Norm sizes of solar modules.

In the US, activities are coordinated by the Institute of Electrical and Electronic Engineers (IEEE), which also actively participates in the IEC Technical Committee to encourage harmonization.

Despite the fact that various international bodies have been working intensively on standardized requirements for grid-connection of PV systems, there is still no common standard or code that is widely accepted. Instead, these issues are mostly covered by national laws, standards, codes or utility recommendations, which have already been established in many of the PVPS countries. Nevertheless several countries still do not have suitable standards for PV. While modules have been the subject of some attention, BOS and systems themselves tend to have had either varying approaches or a complete lack of standards, with consequent trading difficulties. Further information on national requirements in specific PVPS countries can be found in the national survey reports. The broad deployment of PV systems is still often constrained by regulations and requirements, which can increase PV system prices due to the additional equipment, long delays or bureaucratic barriers.

To develop appropriate requirements for stand-alone PV systems in developing countries, the PV Global Approval Programme (PV GAP, www.pvgap.org) set up parallel activities focusing primarily on quality issues. 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 ten 'PV Recommended Specifications' dealing with practical design details, installation guidelines and qualification testing for components. The World Bank has published four manuals setting standards for manufacturing, system design, installation and testing. The common approach remains project specific donor standards rather than developing country national standards.

4 Summary of Trends

Whilst there is great diversity between the countries participating in the IEA-PVPS Programme and although this survey does not capture the whole PV market worldwide, it does provide an indication of global trends. In this report the term 'market' has been used in its broadest sense. Amongst the variety of PV deployments reported there are those that are currently economic, those where added values create an interest and those for which the need for ongoing public support appears firmly entrenched. This report has not explored the issues surrounding the ideal of the 'real' or 'self-sustaining' or 'competitive' PV market.

- The market for PV power applications continues to expand: between 2001 and 2002 the total installed capacity in the IEA-PVPS countries grew by 34 %, reaching 1 328 MW. Of the 338 MW installed during 2002, 79 % were installed in Japan and Germany alone. Doubling of market size in the IEA-PVPS countries has occurred a little more than every two years in recent years.

- Between 1992 and 2002, the proportion of grid-connected PV capacity increased from 29 % to 74 % of the total, up from 68 % in 2001. 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. However, off-grid applications still account for more total installed capacity and new capacity installed in 2002 in the majority of the reporting countries.

- Security of supply issues have raised political interest in all domestic and distributed energy supplies, including PV. Climate change negotiations have raised the profile of renewable energy in general, but the implications for PV remain uncertain. The industry development aspects of PV (including the opportunities to provide jobs) are receiving attention with the publication of a number of 'technology roadmaps.'

- Whilst total national budgets for R & D, demonstration / field trials and market stimulation measures remain strong, there are increasing proportions of the budgets spent on market initiatives rather than demonstration / field trials in many countries.

- Annual module production rose by over 50 % in 2002, to 482 MW. Module production capacity increased by almost 49 % in 2002, to 792 MW. Currently, 47 % of cell production and 54 % of module production in the reporting countries occur in Japan.

- The vast majority of modules produced continue to be based on crystalline silicon material. A number of other technology types are in production but at a much smaller scale. 2002 saw a number of significant developments regarding silicon feedstocks.

- System prices have continued their general downward trend, but include fluctuations and variations between countries, which should be expected given the stage of market deployment and the impact of non-technical factors. More significantly the trend in (current) price reduction for modules (which are internationally traded and can typically cost around 60 % of the system price) shows decreases of between 10 % and 17 % per doubling of market size. Grid-connected systems typically cost about 7 USD per watt, with off-grid systems costing twice this amount. Grid-connected system prices approaching 4 USD per watt have been noted, and prices between 5 and 5,5 USD per watt are more widely reported.

- In general, public opinion appears to be supportive of photovoltaics and electricity utilities are starting to identify many of the opportunities provided by PV. However, the added values of grid-connected PV – electricity network, architectural, environmental and socio / economic benefits – are yet to be systematically incorporated by policy makers and regulators. New stakeholders such as the building and finance sectors now provide additional challenges.

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

Year	Cumulative installed power and percentage increase						Power installed during year (MW)	Module production during year (MW)
	Off-grid		Grid-connected		Total			
	MW	annual growth (%)	MW	annual growth (%)	MW	annual growth (%)		
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	319	15	671	49	990	36	264	319
2002	343[1]	8	969[2]	44	1 328[3]	34	338	482

1 *Does not include Spain*
2 *Does not include Spain*
3 *Estimate for all IEA-PVPS countries*

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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 (sources: OECD Main Economic Indicators May 2003 and Bank of Israel).

Table 11 - Exchange rates

Country	ISO country code	Currency and code	Exchange rate (1 USD=)
Australia	AUS	Dollar (AUD)	1,841
Austria	AUT	Euro (EUR)	1,061
Canada	CAN	Dollar (CAD)	1,570
Denmark	DNK	Krone (DKK)	7,884
Finland	FIN	Euro (EUR)	1,061
France	FRA	Euro (EUR)	1,061
Germany	DEU	Euro (EUR)	1,061
Israel	ISR	New Israeli Shekel (NIS)	4,738
Italy	ITA	Euro (EUR)	1,061
Japan	JPN	Yen (JPY)	125,3
Korea	KOR	Won (KRW)	1 251,0
Mexico	MEX	Peso (MXP)	9,660
Netherlands	NLD	Euro (EUR)	1,061
Norway	NOR	Krone (NOK)	7,986
Portugal	PRT	Euro (EUR)	1,061
Spain	ESP	Euro (EUR)	1,061
Sweden	SWE	Krona (SEK)	9,721
Switzerland	CHE	Franc (CHF)	1,557
United Kingdom	GBR	Sterling (GBP)	0,667
United States	USA	Dollar (USD)	1,000

PV Technology Note

*The key components of a photovoltaic power system are the **photovoltaic cells** (sometimes also called solar cells) interconnected and encapsulated to form a **photovoltaic module**, the **mounting structure** for the module or array, the **inverter** (essential for grid-connected systems and required for most off-grid systems), the **storage battery** and **charge controller** (for off-grid systems only).*

Cells, modules and arrays

Photovoltaic cells represent the smallest unit in a photovoltaic system, typically available in 10 cm, 12,5 cm and 15 cm square sizes. In general, cells can be classified as either crystalline (single crystal or multicrystalline) or thin film. At present, the vast majority of photovoltaic cells are made from silicon. Currently crystalline silicon technologies account for most of the overall cell production in the PVPS countries.
Single crystal PV cells are manufactured using a single crystal growth method and have commercial efficiencies between 12 % and 17 %.
Multicrystalline cells, 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 an average efficiency around 13 %.
Thin film cells are constructed by depositing extremely thin layers of photovoltaic semi-conductor materials onto a backing material such as glass, stainless steel or plastic. Module efficiencies reported for thin film PV are currently ranging from 7 % (a-Si) to 13,52 % (CIS) but they are potentially cheaper to manufacture than crystalline cells. The disadvantage of low conversion efficiencies is that larger areas of photovoltaic arrays are required to produce the same amount of electricity. Thin film materials commercially used are amorphous silicon (a-Si), 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 single crystal cells over 25 %, and for thin film technologies over 19 % being achieved.

Photovoltaic modules are typically rated between 50 W and 200 W but several manufacturers now offer modules up to 300 W. Crystalline silicon modules consist of individual PV cells connected together and encapsulated between a transparent front, usually glass, and a backing material, usually plastic. Thin film modules are constructed from single sheets of thin film material and can be encapsulated in the form of a flexible or fixed module, with transparent plastic or glass as front material. PV modules are guaranteed up to 20 years by manufacturers and must qualify under the IEC 61215 International Standard.
Most complete systems consist of a number of modules connected together in the form of a PV array to give a higher power rating.
A **PV array** consist of a number of modules connected in series (strings), then coupled in parallel to produce the required output power.
A wide range of **mounting structures** has been developed especially for building integrated PV systems (BIPV), including PV facades, sloped and flat roof mountings, integrated (opaque or semi-transparent) glass-glass modules and 'PV roof tiles'.

Grid-connected PV systems

In grid-connected PV-systems, an **inverter** is used to convert electricity from direct current (d.c.) as produced by the PV array to alternating current (a.c.) that is then supplied to the electricity grid. The typical conversion efficiency of inverters is greater than 90 %, with maximum efficiencies up to 97 %. Inverters connected directly to the PV array incorporate a Maximum Power Point Tracker (MPP tracker), which continuously adjusts the load impedance to provide the maximum power from the PV array. One inverter can be used for the whole array or separate inverters may be used for each 'string' of modules. PV modules with integrated inverters, usually referred to as 'AC modules', can be directly connected to the electricity grid.

Off-grid PV systems

For off-grid systems a **storage battery** is required to provide energy during low-light periods. 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 deep-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. Some charge controllers also have integrated MPP trackers to maximize the PV electricity generated.
If there is the requirement for a.c. electricity, a **'stand-alone inverter'** can supply conventional a.c. appliances.

Further details

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

Notes