IEA INTERNATIONAL ENERGY AGENCY

TRENDS IN PHOTOVOLTAIC APPLICATIONS

Survey report of selected IEA countries between 1992 and 2005

PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

Report IEA-PVPS T1-15:2006

TRENDS IN PHOTOVOLTAIC APPLICATIONS

Survey report of selected IEA countries between 1992 and 2005

Contents

Foreword

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization 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 which accelerate the development and deployment of photovoltaic solar energy as a significant and sustainable renewable energy option".

In order to achieve this, the 19 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.

The IEA PVPS Programme is pleased to present the eleventh edition of the international survey report on Trends in Photovoltaic Applications. As in previous years, a strong market growth can also be observed for 2005 with an ongoing trend in grid-connected applications. Industry and markets are becoming ever more dynamic with new players and country developments. For the first time, more than 1 000 MW have been installed in one year in the reporting countries. On the supply side, industry is continuously expanding production capacity, including increasing activities observed in countries that are not members of IEA PVPS. While the main country markets remain Germany, Japan and the US, strong developments are expected in Spain and Italy. Silicon supply issues have increased their impact and pressure on the industry and also continued to adversely affect prices. Nevertheless, signs are increasing that this trend will reverse as further price reductions are a must for sustained market growth. With the subject of energy returning firmly to the political agenda, new opportunities also emerge for photovoltaics. Keeping track of the many developments which characterize the present and affect the future of photovoltaics is an increasing challenge and IEA PVPS is pleased to provide a global network where these issues can be analyzed and discussed. I trust that this new edition of Trends in Photovoltaic Applications will again find many interested readers and I would like to thank all experts who have contributed to this report.

Stefan Nowak
Chairman, IEA PVPS Programme

This report has been prepared by IEA PVPS Task 1 largely on the basis of National Survey Reports provided by Task 1 participating countries. The development of the Trends report has been funded by the IEA PVPS Common Fund and has been approved by the IEA PVPS Executive Committee. To obtain additional copies of this report or information on other IEA PVPS publications visit the IEA PVPS website at www.iea-pvps.org.

August 2006

Introduction

Trends 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 participating countries. The objective of the series of annual Trends reports is to present and interpret developments 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.

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

This report presents the results of the 11th international survey. It provides an overview of PV power systems applications, markets and production in the reporting countries and elsewhere at the end of 2005 and analyzes trends in the implementation of PV power systems between 1992 and 2005.

Survey method

Key data for this publication were drawn mostly from national survey reports and information summaries, which were supplied by representatives from each of the participating countries. These national reports can be found on the website www.iea-pvps.org. Information from the countries outside IEA PVPS are drawn from a variety of sources and, while every attempt is made to ensure their accuracy, confidence in these data is somewhat lower than applies to IEA PVPS member countries.

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 modules is given in watts (W). This represents the rated power of a PV module 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 photovoltaic modules, inverters, storage 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 most benefit from this information) or as euros (EUR) and/or US dollars (USD) (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 conversions in this report are given at the end of this report.

[1] *Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), 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)*

1 Implementation of photovoltaic systems

1.1 Applications for photovoltaics

There are four[2] primary applications for PV power systems:

© Richard Corkish

Off-grid domestic systems provide electricity to households and villages that are not connected to the utility electricity network (also referred to as the grid). They provide electricity for lighting, refrigeration and other low power loads, have been installed worldwide and are often the most appropriate technology to meet the energy demands of off-grid communities. Off-grid domestic systems in the reporting countries are typically around 1 kW in size and generally offer an economic alternative to extending the electricity distribution network at distances of more than 1 or 2 km from existing power lines.

Grid-connected distributed PV systems are installed to provide power to a grid-connected customer or directly to the electricity network (specifically where that part of the electricity network is configured to supply power to a number of customers rather than to provide a bulk transport function). Such systems may be on or integrated into the customer's premises often on the demand side of the electricity meter, on public and commercial buildings, or simply in the built environment on motorway sound barriers etc. They may be specifically designed for support of the distribution electricity network. Size is not a determining feature – while a 1 MW PV system on a rooftop may be large by PV standards, this is not the case for other forms of distributed generation.

© Solar Sales

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 and navigational aids. These are applications where small amounts of electricity have a high value, thus making PV commercially cost competitive with other small generating sources.

Grid-connected centralized systems perform the functions of centralized power stations. The power supplied by such a system is not associated with a particular electricity customer, and the system is not located to specifically perform functions on the electricity network other than the supply of bulk power. Typically ground mounted and functioning inde-pendently of any nearby develop-ment.

© Conergy AG

[2] *Defining systems is becoming more difficult where, for example, large urban grid-connected plants are made up of a number of smaller plants, and mini-grids in rural areas are developed by electric utilities.*

1.2 Total photovoltaic power installed

Yet another landmark was passed in the IEA PVPS reporting countries during 2005 with the installation of over 1 GW of PV capacity during the year, which brings the total installed to 3,7 GW. As in recent years, by far the greatest proportion (85 %) was installed in Japan and Germany alone, and therefore care must be taken when interpreting the results given in this section of the report, as significant developments in other countries can be masked by the level and type of development in these two countries. Figure 1 illustrates the cumulative growth in PV capacity since 1992 within the two primary applications for PV. Particularly with the recent levels of growth seen in IEA PVPS member countries, this reported installed capacity represents a significant proportion of worldwide PV capacity.

The annual rate of growth of cumulative installed capacity in the IEA PVPS countries remained fairly steady at an impressive 42 %, with Germany's cumulative installed capacity growing at 80 % (similar to the previous year) and Japan's growth rate also quite steady at 26 %. The corresponding figures for growth of the annual markets are 40 % for IEA PVPS countries, 75 % for Germany and 6 % for Japan.

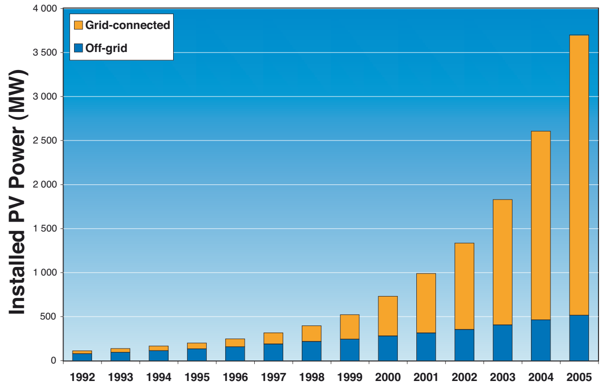

Figure 1 – Cumulative installed grid-connected and off-grid PV power in the reporting countries

Table 1 – Installed PV power in reporting IEA PVPS countries as of the end of 2005

Country	Cumulative off-grid PV capacity (kW)		Cumulative grid-connected PV capacity (kW)		Total installed PV power (kW)	Total installed per capita (W/Capita)	PV power installed in 2005 (kW)	Grid-connected PV power installed in 2005 (kW)
	domestic	non-domestic	distributed	centralized				
AUS	18 768	33 073	6 860	1 880	60 581	2,97	8 280	1 980
AUT	2 895		19 973	1 153	24 021	2,93	2 961	2 711
CAN	5 903	9 719	1 059	65	16 746	0,52	2 862	612
CHE	2 930	320	21 240	2 560	27 050	3,66	3 950	3 800
DNK	70	225	2 355	0	2 650	0,49	360	320
DEU	29 000		1 400 000		1 429 000	17,32	635 000	632 000
ESP	15 800		41 600		57 400	1,32	20 400	18 600
FRA	13 844	6 232	12 967	0	33 043	0,54	7 020	5 900
GBR	227	697	9 953	0	10 877	0,18	2 713	2 567
ISR	809	210	11	14	1 044	0,15	158	2
ITA	5 300	7 000	18 500	6 700	37 500	0,64	6 800	6 500
JPN	1 148	85 909	1 331 951	2 900	1 421 908	11,13	289 917	287 105
KOR	853	4 810	8 028	1 330	15 021	0,31	6 487	6 183
MEX	14 476	4 178	40	0	18 694	0,17	513	30
NLD	4 919		43 377	2 480	50 776	3,12	1 697	1 547
NOR	6 800	377	75	0	7 252	1,58	362	0
SWE	3 350	633	254	0	4 237	0,47	371	60
USA	100 000	133 000	219 000	27 000	479 000	1,62	103 000	70 000
Estimated total	**202 276**	**311 199**	**3 022 416**	**160 909**	**3 696 800**		**1 092 851**	**1 039 917**

Notes: Portugal not included. ISO country codes are outlined in Table 12. Some countries are experiencing difficulties in estimating and/or apportioning off-grid domestic and non-domestic; in some markets the distinction between grid-connected distributed and centralized is no longer clear (eg MW scale plant in the urban environment), and mini-grids using PV are also emerging, with other problems of definition. Where definition has not been made in a national report this is shown in this table, however the totals have been estimated using the most recently available ratio from the national reports applied to the current national data.

These growth rates have resulted in Germany now overtaking Japan with the highest level of installed capacity both in terms of total capacity (1 429 MW) and installed capacity per capita (17,3 W/capita). An important factor behind the levels of growth experienced by these two countries in particular

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

	Cumulative installed PV power (MW)													
Country	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
AUS	7,3	8,9	10,7	12,7	15,7	18,7	22,5	25,3	29,2	33,6	39,1	45,6	52,3	60,6
AUT	0,6	0,8	1,1	1,4	1,7	2,2	2,9	3,7	4,9	6,1	10,3	16,8	21,1	24,0
CAN	1,0	1,2	1,5	1,9	2,6	3,4	4,5	5,8	7,2	8,8	10,0	11,8	13,9	16,7
CHE	4,7	5,8	6,7	7,5	8,4	9,7	11,5	13,4	15,3	17,6	19,5	21,0	23,1	27,1
DNK		0,1	0,1	0,1	0,2	0,4	0,5	1,1	1,5	1,5	1,6	1,9	2,3	2,7
DEU	5,6	8,9	12,4	17,7	27,8	41,8	53,8	69,4	113,7	194,6	278,0	431,0	***794,0***	1 429
ESP	4,0	4,6	5,7	6,5	6,9	7,1	8,0	9,1	12,1	15,7	20,5	27,0	37,0	***57,4***
FIN	0,9	1,0	1,2	1,3	1,5	2,0	2,2	2,3	2,6	2,7	3,1	3,4		
FRA	1,8	2,1	2,4	2,9	4,4	6,1	7,6	9,1	11,3	13,9	17,2	21,1	26,0	33,0
GBR	0,2	0,3	0,3	0,4	0,4	0,6	0,7	1,1	1,9	2,7	4,1	5,9	8,2	10,9
ISR	0,1	0,1	0,2	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,5	0,5	0,9	1,0
ITA	8,5	12,1	14,1	15,8	16,0	16,7	17,7	18,5	19,0	20,0	22,0	26,0	30,7	37,5
JPN	19,0	24,3	31,2	43,4	59,6	91,3	133,4	208,6	330,2	452,8	636,8	859,6	1 132	1 421,9
KOR	1,5	1,6	1,7	1,8	2,1	2,5	3,0	3,5	4,0	4,8	5,4	6,0	8,5	15,0
MEX	5,4	7,1	8,8	9,2	10,0	11,0	12,0	12,9	13,9	15,0	16,2	17,1	18,2	18,7
NLD	1,3	1,6	2,0	2,4	3,3	4,0	6,5	9,2	12,8	20,5	26,3	45,9	49,1	50,8
NOR	3,8	4,1	4,4	4,7	4,9	5,2	5,4	5,7	6,0	6,2	6,4	6,6	6,9	7,3
PRT	0,2	0,2	0,3	0,3	0,4	0,5	0,6	0,9	1,1	1,3	1,7	2,1	2,6	***3,0***
SWE	0,8	1,0	1,3	1,6	1,8	2,1	2,4	2,6	2,8	3,0	3,3	3,6	3,9	4,2
USA	43,5	50,3	57,8	66,8	76,5	88,2	100,1	117,3	138,8	167,8	212,2	275,2	376	479
Total	**110**	**136**	**164**	**199**	**245**	**314**	**396**	**520**	**729**	**989**	**1 334**	**1 828**	**2 607**	**3 700**

Notes: ISO country codes are outlined in Table 12. Source of Spanish data 2000–2005: IDEA, ASIF. Totals reflect conservative 'best estimates' based on the latest information made available to the IEA PVPS Programme from the individual countries for previous years, and are updated as required. Finland no longer included in total.
The reader is referred to the German national report for discussion about the agreed installed capacity in calendar year 2004; both the Spanish and Portuguese figures for 2005 reflect the best estimates available at the time of writing.

Table 3 – A decade of annual market growth in selected countries

	PV power (MW) installed in calendar year										
Country	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
AUS	2,0	3,0	3,0	3,8	2,8	3,9	4,4	5,5	6,5	6,7	8,3
AUT	0,3	0,3	0,5	0,7	0,8	1,2	1,2	4,2	6,5	4,2	3,0
DEU	5,3	10,1	14,0	12,0	15,6	44,3	80,9	83,4	153,0	***363,0***	***635,0***
ESP	0,8	0,4	0,2	0,9	1,1	3,0	3,6	4,8	6,5	10,0	***20,4***
FRA	0,5	1,5	1,7	1,5	1,5	2,2	2,6	3,3	3,9	5,2	7,0
ITA	1,7	0,2	0,7	1,0	0,8	0,5	1,0	2,0	4,0	4,7	6,8
JPN	12,2	16,2	31,7	42,1	75,2	121,6	122,6	184,0	222,8	272,4	289,9
KOR	0,1	0,3	0,4	0,5	0,5	0,5	0,8	0,7	0,6	2,5	6,5
NLD	0,4	0,9	0,7	2,5	2,7	3,6	7,7	5,8	19,6	3,2	1,7
USA	9,0	9,7	11,7	11,9	17,2	21,5	29,0	44,4	63,0	100,8	103,0

Notes: Countries that are experiencing (or have recorded in a past year) annual market demand of >5 MW
The reader is referred to the German national report for discussion about the agreed installed capacity in calendar year 2004 and subsequent implications for the figures above; the Spanish figure for 2005 reflects the best estimates available at the time of writing

was the stable market support mechanisms that initially concentrated on residential grid-connected applications. The impacts of changeable market support frameworks in a number of countries are clearly highlighted in Table 3.
Of the total capacity installed the IEA PVPS countries in 2005 close to 5 % (about 60 MW) were installed in off-grid projects. Figure 3 illustrates the proportion of various PV applications in the reporting countries. One third of countries report off-grid applications as their dominant market. The types of off-grid applications vary between markets. In Scandinavia, the most common off-grid applications are for vacation cottages, whilst in Australia, France and Mexico providing cost effective rural electrification tends to be the main aim. In all these markets, telecommunication and infrastructure applications are important.

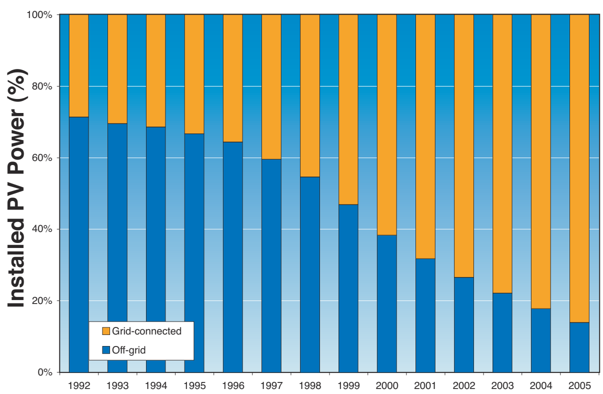

Figure 2 – Percentages of grid-connected and off-grid PV power in the reporting countries

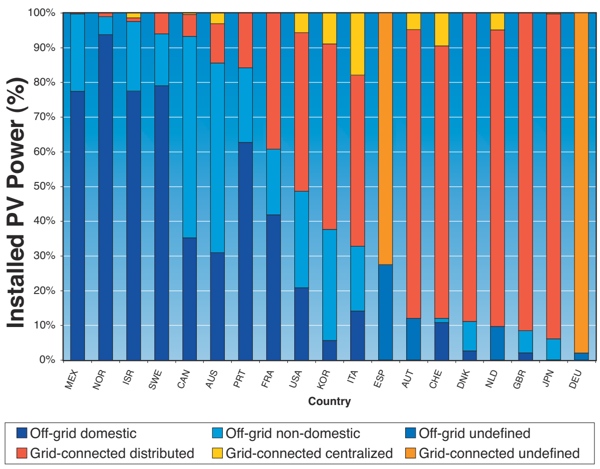

Figure 3 – Installed PV power in the reporting countries by application (%) in 2005

1.3 National PV implementation highlights

The information presented in this section reflects the diversity of PV activity in the reporting countries and the various stages of maturity of PV implementation throughout these countries. For some countries small landmark projects or programmes are as significant as policy debates and PV market expansion are in other countries. The reader is directed to the national information and the case studies on the IEA PVPS website for further details about specific projects and programmes.

Australia (AUS)

The PV Rebate Programme (PVRP) aims to provide government assistance to householders and owners of community buildings, such as schools, to install photovoltaic systems. Other key objectives are to reduce greenhouse emissions, assist in the development of the Australian PV industry and increase public awareness of renewable energy. The programme commenced in 2000 and is currently funded until 2007. 1 042 systems were installed in 2005, amounting to 1,55 MW. 65 % of systems, accounting for 73 % of installed capacity, were on grid-connected buildings and around 4,2 million AUD were allocated in rebates. As part of the Programme, the Australian Government has made available 1 million AUD to fund projects by residential housing developers and display home builders.

The Renewable Remote Power Generation Programme (RRPGP) aims to increase the use of renewable energy for power generation in off-grid and fringe of grid areas, to reduce diesel use, to assist the Australian renewable energy industry, to assist in meeting the infrastructure needs of indigenous communities and to reduce long-term greenhouse gas emissions. In general the target groups are indigenous and other small communities, commercial operations (for example pastoral properties, tourist facilities and mining operations), water pumping and isolated households that operate within diesel grids, use direct diesel generation or are at the end of long grid lines. 2,08 MW of PV were installed under RRPGP in 2005, bringing the total installed capacity to 5,35 MW under this programme, of which 0,81 MW is installed in large utility run diesel grid systems. The latter includes 0,43 MW of solar concentrating dishes commissioned in the Northern Territory, with an additional 0,29 MW to be commissioned in early 2006. Although the Programme is not PV specific, over 95 % of small systems installed under the RRPGP include some PV element. The overall programme has funds of around 205 million AUD allocated, of which around 141 million AUD had been committed by the end of 2005.

Austria (AUT)
With the introduction of the national support for electricity from renewable energy sources (Green Electricity Act) in 2003, the local and regional PV programmes initiated by communities, federal states or utilities have largely ceased or were adapted to the national scheme. After the total capacity limit allocated for PV feed-in tariffs was reached in early 2003, some provinces again re-established regional market incentives to overcome the severe lack of federal incentives and avoid a total collapse of the local PV market. In 2005 such support in the form of investment subsidies was provided by three of nine provinces, while on the national level, no further incentives were available.

The recent trend towards optimal architectural integration of BIPV in newly constructed and refurbished buildings continued during 2005. Several installations with innovative design aesthetically integrated into buildings have been completed. Some outstanding examples in 2005 included the SOL4 Business and Training Centre, Eichkogel, Lower Austria, which was developed as part of the national 'House of the Future' programme and the first church building in Austria developed according to passive house standards with façade integrated PV providing the electricity supply. In the capital Vienna, the municipality integrated three BIPV technologies in the refurbishment of an historic office complex.

Canada (CAN)
In partnership with industry in 2005, the Canadian Government unveiled a new federal building in Yellowknife, Northwest Territories, as an environmental showpiece for the North. The new Greenstone Building will house about 200 public service employees from approximately 15 different federal departments and is scheduled to become the first 'North of 60' Leadership in Energy and Environmental Design (LEED®) Silver-certified project. The LEED® standard, originally developed in the USA and recently adopted in Canada, provides an effective and consistent framework for gauging sustainable building design. The building incorporates innovative energy conservation measures and 33,5 kW of PV in a south-facing curtain wall that integrates PV laminated glass and an interior circuit wiring system in modular frames of energy efficient glazing systems.

The Canadian Government through a TEAM-funded technology demonstration project assisted the Canadian industry to develop and grow the Canadian market for emerging innovative photovoltaic energy technology. The project led to the development of an advanced control system and platform that can enable photovoltaic, wind, fuel cells and alternative power systems to be optimally integrated into conventional fossil fuel-based power generating systems for remote and off-grid power applications.

The Canadian Government's On-Site Generation at Federal Facilities initiative was completed on March 31 2005 and resulted in 13 PV systems being installed at various federal facilities.

Denmark (DNK)
Denmark has no unified national PV programme but numerous projects have been supported mainly by the Danish Energy Authority and also through the Public Service Obligation (PSO) of the Danish transmission system operator. Since 1992 the Renewable Energy Development Programme of the Energy Authority has supported about 125 PV projects and by the end of 2005 about 2,65 MW of mostly demonstration plants have been installed. Since early 2004 the Danish Energy Authority in collaboration with the electricity sector, the industry and other key stakeholders has had a national PV strategy that includes research, development and demonstration, but not deployment.

Following the SOL 300 project, launched early 1998, the most high profile project for 2005 has been the SOL 1000, now targeting about 650 kW of BIPV. Turn-key PV system costs for standard roof-top systems in the project are around 34 DKK/W. The SOL 1000 project has as an accompanying measure a multi-faceted R&D project package named SOL 2000A funded by the PSO facility of the Danish transmission system operator.

A special support programme for PV applications in the commercial sector, funded by the CO_2 tax on electricity, was set up in early 1998. The support includes a subsidy of up to 36 % for the turn-key costs, with the subsidy payment favouring high yield installations. However, little use is made of this subsidy scheme as the commercial sector is eligible for tax refunds on electricity and the value of the substituted solar electricity is consequently low.

France (FRA)
In 2005 for the first time several distributed grid-connected PV projects of the order of 100 kW were realized. Examples include a parking lot roof, a tramway shed and façades in high-rise social buildings. The largest project is a 446 kW system using flat-roofing material based on amorphous silicon on stainless steel substrates, encapsulated in polymeric membranes. While these systems are not currently monitored, it is planned to do so on some of them in the future. PV installation grew 30 % from 2004 to 2005 to reach 7 MW, of which 6 MW were grid-connected. This confirms the observation of an orientation towards grid-connected PV since 2003.

The main providers of subsidies to install PV systems in France are ADEME, the Regional councils and the European Commission (structural development funds). In general, PV projects are private initiatives and are not demonstration or field test operations initiated and coordinated by ADEME. Some projects are funded by the Directorate General Transport and Energy (DG TREN) of the European Commission. Two of these, co-funded by ADEME, were completed in 2005. The PV-STARLET project, in partnership with the Hespul association and some European tile manufacturers, among them Imerys–Toiture, has allowed the installation of 420 kW of photovoltaic tile systems on approximately 200 houses. The UNIVERSOL project, also coordinated in France by Hespul, resulted in the installation of 290 kW of grid-connected systems on 12 educational buildings.

A new initiative by the Languedoc-Roussillon Regional council launched a request for proposals to install 1 MW of BIPV systems in buildings under the condition that they include demonstration capability, energy efficiency and potential for duplication.

Germany (DEU)

In 2005 the PV market in Germany grew up by about 75 % to more than 600 MW of newly installed PV capacity. The market was characterized by a huge demand and simultaneous tension in the supply of silicon, and an increase in prices of PV systems.

The PV industry achieved a turnover of about three billion EUR and employed 25 000 people. PV producers are increasing their capacities and generating further employment.

The high buyback rates of the Renewable Energy Sources Act (EEG) have driven the industry and market. In 2005 the feed-in tariff for PV electricity was 0,513 EUR/kWh for rooftop systems.

Following the success of the 'soft loan' 100 000 Rooftops Solar Electricity Programme which ended at the end of 2003, support of PV by soft loans is maintained through other programmes of the KfW Promotional Bank. A new programme in 2005, Solar Power Generation, has seen 16 000 loans with a total volume of 500 million EUR granted.

Other programmes of the Federal States (Länder) and the Federal German Environmental Foundation (DBU) are designed for local or project specific support of PV. Also, a number of utilities have launched initiatives to build PV demonstration and pilot systems or to provide advice and information.

In 2005 extra funds were made available for the realization of the PV Technology Evaluation Centre (PV-TEC). PV-TEC deals with the development of new silicon PV cell concepts and is designed to facilitate the transition from laboratory to production. While the BMU supported the initial set up of PV-TEC, the operation of the centre will be financed by cooperative R&D projects involving industry and research groups.

Israel (ISR)

The Darajat solar community is an Arab agricultural village located in the Negev desert and not connected to the electricity grid. The project was proposed and initiated by the Ministry of National Infrastructures (MNI), Department of Energy Conservation, with joint funding of 304 000 USD provided by the Ministry of National Infrastructures and the Negev Development Authority, Office for Development of the Negev and Galilee.

The first stage was installed by late 2005, consisting of 20 household systems of 1 kW each (out of a total planned 80 dwellings, constituting the entire village), the school's science room (for educational purposes), the mosque and six streetlights, totaling 22,5 kW. There is every intention of completing the project through private funding thereby serving as a model for similar communities in Israel.

Italy (ITA)

The Regional Roof-top Programmes are completely managed by the Italian Regions and continued throughout 2005. Despite very high public demand, ongoing bureaucratic issues in some regions have resulted in slower than anticipated uptake. As a consequence, at the end of 2005 some regions had yet to complete their own Programme and only about 15 MW out of the anticipated 21 MW have been installed so far.

The activities performed within the framework of the Demonstration Programme include the analyses, tests, long term performance evaluations as well as operation and maintenance procedures carried out by ENEA (the Italian Agency for New Technology, Energy and Environment) on its own plants and on BIPV systems installed on public buildings of some municipalities and universities. In addition, performance evaluation of PV components and plants are carried out by CESI (Institute for Certification of Electric Components and Systems), through its research company CESI Ricerca, in order to assess long-term behaviour of PV technology in different climatic conditions and in different electric configurations.

The Feed-In Programme, launched in September 2005, has created an expectation of strong market growth in Italy. The feed-in tariff applies to PV that satisfies the following criteria: the system must be connected to the low or medium voltage grid, have components that satisfy technical standards, have a generation capacity between 1 and 1 000 kW and have begun operation after 30 September 2005. The tariff for the total produced electric energy varies with the nominal power of the plant and ranges from 0,445 EUR/kWh to 0,490 EUR/kWh. The duration of the support is 20 years and the tariffs are updated on a yearly basis, taking into account the official inflation rate. A tariff reduction of 5 % per year is applied to PV plants requesting support after 2006. The electricity produced by the PV system can be used on-site or sold to the local utility.

Japan (JPN)

The Residential PV System Dissemination Programme subsidized the PV installation cost for individuals on condition that they made available the operational data of their systems. In 2005, 39 963 applications corresponding to 155,7 MW of residential PV systems were accepted and the Programme was terminated in October 2005 as the budget for FY 2005 was exhausted. The subsidy for 2005 was 20 000 JPY/kW, compared to 45 000 JPY/kW in 2004. As of the end of FY 2004, the cumulative installed capacity of residential PV systems installed under this programme reached 795,3 MW (217 000 PV systems).

The Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications started in 1998 aimed at private companies, local public organizations and other organizations, proposing to install modular type PV systems and novel application PV systems. Half of the PV installation cost was subsidized. Installation of PV systems finished in 2002 but collection and analysis of the data continued throughout 2005. The Field Test Project on New Photovoltaic Power Generation Technology started in 2003 as a successor to the previous field test programme, with the aim of adopting new PV technologies for public and industrial facilities and accelerating further development. Eligible applicants for the projects are private businesses, local authorities and organizations. As co-researchers, they collect performance data of the PV system for five or six years and demonstrate the performance of the system. A subsidy of 50 % of the installation cost is available. In 2005, a total of 574 projects accounting for 23 960 kW were selected for funding.

The Project for Promoting the Local Introduction of New Energy aims to accelerate introduction of new energy by supporting regional projects established by local governments, and nonprofit projects for introducing new energy systems by nonprofit organizations (NPOs). The number of local governments and municipalities using this programme has been increasing year by year. The project was started in 1997 and NPOs became eligible in 2005 in addition to local governments. PV systems of over 10 kW generation capacity are now eligible for funding (previously the output capacity needed to be over 50 kW). Up to one half of the total system installation cost is subsidized, the level of support being determined on a case-by-case basis. In 2005, 33 PV systems (870 kW in total) were supported for city halls and water treatment plants, primary and junior high schools, kindergartens and so on. This compares to 2004 where 45 PV projects (3 433 kW in total) were selected. It is anticipated that the cumulative capacity of PV systems installed to 2008 will be 22 599 kW, involving 226 systems in total.

Government of Canada Greenstone Building, Yellowknife, Northwest Territories (Photo Visionwall)

In 2005 the Project for Supporting New Energy Operators saw the selection of three PV projects aiming to install 80,58 kW. This project launched in 1997 aims to accelerate new energy introduction by supporting the private businesses that introduce various technologies. Successful applicants receive a subsidy of one third of installation costs and are guaranteed over 90 % of the debt. While PV systems are mainly introduced to factories under this project, systems for all-electric condominium buildings have also been installed.

The Eco-school Promotion Pilot Model Project was initiated in 1997 and now involves the partnership of the Ministry of Energy and Trade (METI), the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Agriculture, Forestry and Fisheries Ministry (MAFF) and the Ministry of the Environment (MoE). The project aims to implement pilot model projects that promote environment-friendly schools, providing students with environmental education and also improving school facilities. In 2005, 55 PV projects in schools were approved.

Korea (KOR)

The Ministry of Commerce, Industry and Energy (MOCIE) has been implementing, via an affiliate of the national energy utility KEMCO, demonstration and field testing of various renewable energy technologies. In 2003, the 2nd 10-year basic plan for new and renewable energy RD&D was established to enhance the level of self-sufficiency in energy supply, to meet the challenge of climate change and to consolidate the infrastructure of industry.

Under the Renewable Energy Demonstration Programme, during 2005 a 1 MW PV power demonstration programme was being developed with Seoul Marine Corporation at the Suncheon City on the southern coast of Korea and will be operational in 2006. Various grid-connected PV systems with capacities of 5-30 kW were installed in schools and universities.

The Rooftop Programme saw 907 1-3 kW systems (2 403 kW in total) installed with a budget of 16 billion KRW in 2005. 310 systems were installed in 2004. The system owners paid 30 % of their total system price.

The Feed-in Tariff Programme has been implemented with a fixed price of 716,40 KRW/kWh guaranteed for 15 years for systems over 3 kW. The first phase of this programme ends in October 2006, after which the feed-in tariff will be revised. The Korean government will apply 716,40 KRW/kWh up to 20 MW cumulative installed capacity, with a ceiling of 3 MW per company. Several projects of multi-MW scale are in the planning stage with local government and local utilities or foreign companies.

Several PV rooftop systems are being tested as part of the Renewable Energy Field Test Programme at the Solar Energy Field Test Site at Chosun University in Gwangju metropolitan city. System performances and reliability are tested and evaluated.

Under the local energy development project, a wide variety of PV systems including off-grid domestic, non-domestic and grid-connected systems were constructed. In 2005 the government allocated more than 40 billion KRW for all renewables systems with PV being allocated about 21 % of this total. Local authorities provide support equivalent to 30 % of the system cost and carried out a variety of PV system installations aimed at increasing public awareness of PV and developing PV as an indigenous renewable energy source for their region. Several local authorities started planning 'Green Village' projects, which will incorporate PV power systems and solar thermal systems.

Mexico (MEX)

Rural electrification remains the main application of PV in Mexico. Since 2000 water pumping for productive uses in agriculture has been supported with Global Environment Facility (GEF) funds. With a budget close to 30 million USD, the programme installed about 2 000 water pumping systems, electric fences and cold tanks in order to enhance the productivity of small rural producers.

No demonstration projects or field test programmes were carried out during 2005. However, recent studies carried out in preparation for a forthcoming rural renewable energy electrification programme (to be co-funded by the GEF, the World Bank and the Mexican Government) showed that PV would be the least expensive alternative in more than 51 % of almost 9 500 targeted communities in four southern states.

The Netherlands (NLD)

A new demonstration programme was introduced, the so-called EOS – Demo (Energy Research Subsidy – Demonstration). However in 2005 no PV projects were funded within this scheme. A few projects, funded under the former BSE-DEN programme, which closed in 2003, were still running throughout 2005.

In order to stimulate energy reduction the central government supports municipalities and provinces through the BestuursAkkoord Nieuwe Stijl (BANS) agreement. It includes support for the municipalities and provinces to implement measures promoting energy reduction and renewable energy. In 2005 about 200 municipalities actively participated in the programme.

Norway (NOR)

There were no national demonstration or field test programmes in operation in 2005.
However, a few demonstration projects for building integrated PV have been installed over recent years. Among these are The Norwegian University of Science and Technology (NTNU) in Trondheim (16 kW), the British Petroleum administration building in Stavanger (approximately 16 kW), the low-energy dwelling at Hamar (2,2 kW), and a 5,2 kW grid-connected system installed at a rehabilitation centre in Kristiansand, all installed before 2004.
The most exciting building integrated project currently being planned is the use of transparent double glass modules on the southern façade of the new opera house in Oslo, located in the harbour area. The 35 kW system will serve partly as a solar shading device, and partly be integrated in the façade. This is part of an EU project, EcoCulture, and installation will take place in 2006.

Spain (ESP)

No demonstration programmes / projects have been reported for 2005. A feature of the Spanish market is the proliferation of 'solar farms' – installations of approximately 100 kW with several owners, none owning more than 5 kW as a consequence of a previous administrative limitation. With the removal of the 5 kW limitation, a feed-in tariff that now allows grid-connected PV investments to be profitable and a positive public perception of PV, the market environment in Spain is buoyant.

Sweden (SWE)

In 2005 a project that has been interesting for grid-connected applications was installed at ABB's company facilities in Västerås. The aim of this project was to discern what barriers exist for grid connection, and the electricity retail arrangements for a typical domestic roof-top system. The results from this 3 kW project showed that the legislation as it applies to feeding electricity into the grid does indeed raise obstacles for smaller scale systems.

In the city of Malmö several projects involving PV have been launched as part of a programme to strengthen the city's environmental profile. One of these projects, a demonstration system in Augustenborg, was completed in 2005 and several more will follow during 2006 and 2007 with support from Sweden's new investment subsidy for PV in public buildings.

A novel project for Sweden is the development of a PV marketing strategy, whereby the PV production is offset by the heating requirements of the house. The premise is that the PV system should produce the same amount of energy on a yearly basis that a heat pump consumes when heating the house. Since there are legislative and economic barriers that inhibit the application of grid-connected PV on a small scale in Sweden alternative solutions have been sought. The project is led by the company Ekosol AB in Strängnäs, with partner companies from the PV, building and financial sectors. In the first stage, 16 houses with roof integrated PV will be built in Strängnäs. Ekosol rents the PV system from the house owner for a fixed fee and sells the electricity to the grid. The customer receives a rebate on the mortgage interest that corresponds to the interest cost for the PV system.

Switzerland (CHE)

The equipment manufactures in Switzerland profited very well from the booming market. The estimated turnover for the Swiss PV industry in 2005 is about USD 250 Mio.

The activities of the electricity utilities in the field of solar power 'stock-exchanges' have increased slightly, particularly through the efforts of the BKW and SIG organizations which, on their own initiative, each built and put into operation a large PV installation (855 kW and 1 MW respectively). Other projects of note include the 'Zollhof' 23,5 kW system in Kreuzlingen, designed to achieve a high level of public identification, and the 62,4 kW flat-roof elements system for Trisa Electro in Triengen. Also, the measurement campaign on the 24,5 kW thin-film test installation at Migros in Zurich is continuing. This project uses a number of different technologies (a-Si, CIS and, as a reference, multi-crystalline silicon) supplied by six different manufacturers and measures their performance in detail for more than 2 years.

United Kingdom (GBR)

2005 saw continued growth of the UK PV industry, both in terms of installed capacity, manufacturing output and number of staff employed in PV activities. The vast majority of new installed capacity in 2005 was partly funded under the UK Government Major Demonstration Programme. This programme ended in March 2006 and the final installations funded by the scheme will be completed by March 2007. Continued grant support will be provided by the Low Carbon Buildings Programme which forms part of the new Government strategy for the promotion of micro generation technologies (small scale renewables and micro-combined heat and power including PV, small wind, solar water heating etc.). The new Microgeneration Strategy aims to tackle the wider barriers to the development of sustainable markets for small scale renewables and combined heat and power. It sets out a list of wide-ranging actions, including an accreditation scheme for products and installations, a review of planning procedures, a pilot scheme to assess the benefits of smart metering, as well as the Low Carbon Buildings Programme, all of which should be of benefit to development of the PV industry.
Public funding for PV research and development is focused on supporting projects to develop novel materials offering significant improvements in performance, reliability and generation costs. There are several long-term projects under way involving industry and universities from which encouraging results are beginning to emerge.

United States of America (USA)

The major PV activities underway in the United States consisted of the continuation of the state funded projects started in the 1997–1999 time frames and the addition of new state incentives in 2003 through 2005 – particularly California, New Jersey, Arizona, and New York. State-supported installations of PV grew 20 % from 52 MW in 2004 to 62,4 MW in 2005 as reported by the Interstate Renewable Energy Council (IREC).

In California installations in 2005 grew about 16 % from 44 MW to 51 MW. The rate of growth slowed in 2005 due to the uncertainty and transition to the new California 'million solar roofs' programme to be managed by the California Energy Commission. The new programme will start in 2006 and will continue for ten years. The goal of the programme is to decrease the subsidy each year, to stimulate lower installed PV system costs so that PV is 'economical' without subsidies by 2016. An existing programme initiated by California in 2001 with rebates of 4,50 USD/W to residential and commercial customers has resulted in nearly 60 MW of installed grid-connected PV systems on investor-owned utility grids. A total of 20 MW of PV was installed in 2005 with the subsidy rate having decreased to 2,80 USD/W. California also has a programme of renewable set-asides administered by the California Public Utilities Commission. Over 20 MW were installed by the four key utilities – Pacific Gas and Electric, Southern California Edison, San Diego Gas and Electric, and Southern California Gas Company.

New Jersey is implementing one of the most aggressive PV support programmes in the United States with over 100 million USD being allocated to the programme. Nearly 2 MW of PV were installed in New Jersey in 2004 and 2005 total installations grew to 5,5 MW. New York has legislated over 150 million USD to support new industry, new installations, and studies to accelerate commercialization of PV systems and has recently increased the PV subsidy to 5 USD/W for grid-connected systems. Estimates from IREC indicate that 1,34 MW of PV were installed in New York State in 2005. Massachusetts, Texas and Oregon all use a combination of renewable portfolio standards (RPS), state demonstration projects and tax credits, and each reported installations of about 0,5 MW in 2005.

Other countries

Verifying total market volume and other data for non IEA PVPS countries is difficult, especially due to the often large number of small systems involved. The following descriptions are not exhaustive. They are intended to give an indication of the scale of a selection of international markets and an overview of market drivers to allow the IEA PVPS data to be viewed in the context of global PV developments.

Bangladesh
Although almost ¾ of households in Bangladesh are not connected to the electricity grid, the Bangladeshi government has expressed a vision of nation-wide access to electricity by 2020. Solar home systems are an important component of achieving the universal electricity objective and are becoming increasingly attractive in the current cycle of kerosene price increases. Current total installed PV capacity is about 3 to 4 MW.

China
In 2005 China again led the market for PV equipment outside of the IEA PVPS countries, with annual sales of about 5 MW and total installed PV capacity reaching 70 MW. Remote and rural electrification accounts for approximately 50 % of the annual market, including solar home systems, village power and pumping applications. The Song Dian Dao Cun (National Village Electrification Programme) is expected to deliver solar power to 10 000 villages (265 MW) by 2010 and a further 18 000 villages (1 700 MW) by 2020. The Renewable Energy Law (REL) came into effect on 1 January 2006 as the principal national policy framework supporting the Chinese Government's expressed intent to meet 15 % of gross energy consumption with renewable energy by 2020. The REL includes support for PV via a feed-in tariff, preferential taxes and loans, and specific encouragement of building related solar.

**European Union –
New Member and Candidate States**
All NM&CS except for Bulgaria have adopted strategies for renewable energy development mainly in response to international obligations. Only Poland and Romania have set specific indicative values for PV in 2010 (2 and 1,5 MW, respectively). In the majority of the NM&CS countries PV is placed within general research or energy schemes. The Czech Republic is a significant exception, with a demonstration programme 'Sun to Schools', and a new Act on the promotion of electricity from renewable energy sources involving preferential grid interconnection rules, purchase obligations and financial incentives – green bonuses and a PV feed-in tariff. PV system installations in public buildings are also planned by the national administration of Cyprus. Of the 1,8 MW of total installed PV capacity in the NM&CS countries about one half is found in the Czech Republic and Cyprus.

India
The Ministry of Non-Conventional Energy Sources (MNES) has been supporting PV dissemination and development for over a decade. Of the 80 – 90 MW of total installed PV capacity in the country, MNES programmes account for about 50 %. MNES estimates that 5 000 MW of grid-connected PV power could be feasible by 2032.

Malaysia
Although grid-connected PV currently amounts to less than 15 % of Malaysia's total installed PV capacity of 3 MW, the domestic PV market development priorities are clearly focused on the grid-connected, building integrated sector. The five year 25 million USD Malaysian Building Integrated PV (MBIPV) project commenced during 2005, with the aim of reducing costs and establishing the necessary mechanisms to create sustainable opportunities for BIPV in the Malaysian market.

Sri Lanka
The primary driver of PV market development in Sri Lanka is currently the Renewable Energy for Rural Economic Development (RERED) Project. RERED aims to expand the commercial provision and use of renewable energy, particularly to increase rural access to electricity, with a focus on improving the quality of life and economic development. The project will provide around 28 million USD specifically for solar PV investments (alongside other renewable energy technologies, energy efficiency and demand side management measures). The current total installed PV capacity is about 3,9 MW.

1.4 Budgets for market stimulation, R&D and demonstration

The public budgets for market stimulation, research and development, and demonstration and field trials in 2005 in the IEA PVPS countries vary widely, with the total public expenditure being quite similar to that for 2004 at around 1 billion US dollars. The situation varies from country to country (see Table 4 for 2005 budgets) and the boundaries of what constitutes 'research', 'development', 'demonstration / field trials' and 'market stimulation measures' often vary from country to country. Again, in about half the cases the total budget showed an increase from the previous year, particularly evident for Korea.

2005 saw a levelling of the previously steady yearly increase in total budget and a slight decrease in the support for both R&D and Demonstration / Field Trials compared to 2004; however, the following general long-term trends and observations for the IEA PVPS countries, reported last year, remain valid:

- over the previous decade, public spending on PV has doubled;
- initially this spending was largely focused on RD&D;
- the amount spent on market stimulation increased at the expense of RD&D (in both absolute and relative terms) until 2001;
- 2004 saw the previously steadily increasing budgets for market stimulation decrease for the first time in a decade.

European Union (EU) R&D funding support for PV has grown from less than 20 million EUR in the 1975-1979 Energy R&D Programme to 95 million EUR in Framework Programme (FP) 6 (2002-2006). However, this represents a decrease from the peak of approximately 120 million EUR allocated for PV R&D in FP5 (1998-2002). The decrease has been almost exclusively in the area of demonstration, with research expenditure remaining around the 70 million EUR level. The allocation of PV R&D funding in FP6 is as follows: thin film 26 %, crystalline silicon 24 %, deployment and integration 15 %, new concepts 13 %, systems 7 %, pre-normative 7 %, co-ordination and support 5 % and III-V concentration 3 %. The allocation represents the interests of the European Commission rather than a summary of the priorities of the EU member countries. The reader is referred to the individual national reports for the highlights of R&D activities in each country. For information on individual European Commission projects the reader is referred to: http://ec.europa.eu/research/energy/nn/nn_rt/nn_rt_pv/article_1109_en.htm .

Table 4 – Public budgets for R&D, demonstration / field trials and market stimulation in 2005

Country	R&D		Demonstration/ field trials		Market stimulation		Total	
	EUR	USD	EUR	USD	EUR	USD	EUR	USD
AUS	3,11 M	3,84 M	0	0	13,08 M	16,15 M	16,19 M	19,99 M
AUT	0,64 M	0,79 M	0	0	4,80 M *(note)*	5,93 M	5,44 M	6,72 M
CAN	4,55 M	5,62 M	0,54 M	0,66 M	0,07 M	0,08 M	5,16 M	6,36 M
CHE	9,00 M	11,12 M	0,19 M	0,24 M	1,10 M	1,36 M	10,30 M	12,72 M
DNK	6,10 M	7,50 M	0,60 M	0,70 M	0	0	6,70 M	8,20 M
DEU	42,0 M	51,9 M			*(See German national report for details about feed-in tariff programme)*			
ESP							0,53 M	0,65 M
FRA	12,50 M	15,40 M	0	0	15,00 M	18,50 M	27,50 M	33,90 M
GBR	4,29 M	5,29 M	13,48 M	16,64 M	0	0	17,77 M	21,93 M
ISR	0,14 M	0,17 M	0,25 M	0,30 M	0	0	0,39 M	0,47 M
ITA	4,80 M	5,90 M	0,20 M	0,25 M	30,00 M	37,00 M	35,00 M	43,20 M
JPN (METI)	30,16 M	37,24 M	77,91 M	96,19 M	19,12 M	23,61 M	127,19 M	157,04 M
KOR	4,77 M	5,89 M	5,75 M	7,10 M	48,49 M	59,86 M	59,01 M	72,85 M
MEX	0	0	0	0	0	0	0	0
NLD	10,90 M	13,50 M	0	0	1,80 M	2,20 M	12,70 M	15,70 M
NOR	1,06 M	1,30 M	0	0	0	0	1,06 M	1,30 M
SWE	1,96 M	2,42 M	0,19 M	0,24 M	0	0	2,15 M	2,66 M
USA	61,40 M	75,80 M	0,81 M	1,00 M	145,80 M	180,00 M	208,01 M	256,80 M

Notes: ISO country codes are outlined in Table 12. Austria – the feed-in tariffs paid for PV in 2005 amounted to about 8,4 million EUR.

2 The PV industry

This section provides information on the industry involved in the production of PV materials, cells, modules and system components during 2005. The industry may be subdivided into the following groups representing different steps in the PV value chain:

- producers of upstream materials, i.e. feedstock, ingots, blocks/bricks and wafers
- producers of semi-finished and finished PV products, i.e. PV cells and modules
- producers of balance-of-system components for PV systems, i.e. charge regulators, inverters, batteries, mounting structures, appliances etc.

A regional overview of PV cell and module manufacturing in the IEA PVPS countries during 2005 is presented in Table 5, which likely accounts for about 90 % of the worldwide production. China and Taiwan have a rapid development of cell and module manufacturing capacity.

2.1 Feedstock, ingots and wafers (upstream products)

Crystalline silicon wafers remain the dominant substrate technology for making PV cells. For the second year in a row IEA PVPS is reporting on production of feedstock, ingots and wafers and the corresponding production capacities in the IEA PVPS countries. (The discussion in this section does not refer to thin film technologies). This section is provided in the interest of completeness and is largely based on the information available from participating countries.

Feedstock

To make single crystal silicon ingots, multicrystalline silicon ingots or multicrystalline silicon ribbons the basic input material is highly purified silicon. The ingots need to be cut into bricks or blocks and then sawn into thin wafers, whereas the ribbons are cut to wafers of desirable size.

Until 2000 the traditional silicon feedstock for the PV industry consisted of rejects from the semiconductor industry. Because of the tremendous growth of PV business the main source now is virgin silicon. The process is the same as for producing semiconductor grade silicon. However, the producers have simplified some steps in their processes for supplies to the PV industry. There are many attempts to replace the current expensive purification process based on chemical gaseous purification by cheaper alternatives including metallurgical purification (condensed phase). Although significant progress has been achieved during recent years and several pilot plants have been put into operation, none of these new materials have yet been introduced to the market and are not expected to come on-stream before 2007-2008 at the earliest.

There are seven companies and ten plants producing PV grade silicon in four IEA PVPS countries. Outside the IEA PVPS countries the production of silicon is negligible. The total production capacity of about 30 000 metric tonnes (t) was probably close to the actual output, of which about 11 000 t were sold to the PV industry.

The total consumption of silicon by the PV industry was in all likelihood close to 15 000 t (enough to

Table 5 – PV cell and module production in 2005 by world region – IEA PVPS countries

		Japan	USA	Europe	Rest	Total
Cell Production	**All types, MW**	**824**	**156**	**479**	**41**	**1 500**
Cell Production Capacity	**MW / year**	***1 071***	***207***	***811***	***63***	***2 152***
Module Production	**sc-Si, MW**	159	58	118	1	**336**
	mc-Si, MW	461	50	116	33	**660**
	a-Si, MW	33	22	2	–	**57**
	Undefined Si, MW	120	42	270	11	**443**
	Other, MW	–	26	9	<1	**36**
	Total MW	**773**	**198**	**515**	**46**	**1 532**
Module Production Capacity	**MW / year**	***1 286***	***257***	***791***	***193***	***2 527***

Notes: mc-Si includes modules based on EFG and String Ribbon cells. 'Undefined Si' means the Si technology type was not clarified; 'other' refers to technologies other than silicon based. 'Rest' refers to Australia, Canada, Israel, Korea and Mexico.

produce roughly 1 150 MW of crystalline silicon PV cells) in 2005, the balance being provided by remaining inventories and rejects from the semiconductor industry (recycled wafers, pot scrap, tops and tails etc).

With five plants, the USA is the largest producer of silicon (15 750 t) and worldwide supplier of this product to the PV industry (6 300 t). Most of the production is exported to Europe and Japan. USA is followed by Japan with three plants producing 8 000 t, of which only a minor part goes to the PV industry (1 300 t to 1 400 t). In Europe the German company Wacker is the second largest worldwide producer (5 200 t to 5 500 t). This company seems to have allocated more than half of its production to PV in 2005 (3 000 t).

The largest companies (Hemlock, USA, REC Silicon, USA, and Wacker, Germany) have all announced significant expansion programmes. A first wave of an additional 20 000 t should come on line in 2008–2009. Some of these expansion projects will make use of new technologies, particularly the replacement of the Siemens reactors by fluidized bed reactors for the deposition of silicon. Newcomers have also announced plans to enter the silicon business (M-Setek, Japan). However, none of these are in the construction phase. Outside the IEA PVPS countries there are silicon projects under discussion in Russia, the Ukraine, Kyrgyzstan and China.

Because of tightening of supply of low cost feedstock, R&D on new processes has seen a promising renaissance. Chemical companies are developing more cost efficient processes: fluidized bed reactors (REC Silicon, Wacker), free space reactors (Joint Solar Silicon, a joint venture between Degussa and Solar World of Germany), vapor to liquid deposition (Tokuyama) etc. Besides these developments through chemical processes, several companies are exploring the metallurgical route. Leading these is Elkem of Norway which in 2005 decided to build a pilot plant with commercial potential by 2007–2008. FerroPem/Invensil in France also has a project following this route.

Ingots and wafers

Ingots are of two types: single crystal and multicrystal. The first type is also produced for microelectronics applications, while multicrystalline ingots are only used in the PV industry. Ingot producers are in many cases also producers of wafers. Three companies are in the lead of this industry and continued in 2005 to increase their capacities (by around 35 %–50 %): REC wafers of Norway, Deutsche Solar of Germany and PV Crystalox of the UK and Germany.

Some companies are vertically integrated, controlling the process from ingots to cells and modules. *Commentary – These companies however appear to put more effort into increasing their cell production capacity than that for ingots and wafers. Newcomers also appear to have difficulties increasing their capacity for ingots and wafers. This seems to be the case for Kyocera in Japan, BP Solar and Shell Solar in the USA, Photowatt, Schott Solar, Emix and several others in Europe.*

The companies having their own feedstock, for example REC wafers, or having secured long term contracts are those best able to grow. On the technology side, single-crystal technology is regaining ground. Offering higher efficiency, these cells consume less feedstock per watt but require a substrate of higher quality. Ribbon technologies are represented by two companies whose importance remains moderate. A very interesting trend is the impressive decrease of wafer thickness, probably strongly motivated by the rising price of silicon feedstock and an ongoing focus on improving manufacturing efficiency.

In summary, the trends in the ingot and wafer business are determined by two factors: the continued strong demand for products downstream (cells, modules, systems) and the availability of low cost silicon feedstock upstream.

2.2 Photovoltaic cell and module production

The PV cell and module manufacturers continue to grow strongly. The reader is directed to the individual national reports for a comprehensive summary of manufacturers and production in each of the countries.

The total photovoltaic cell production volume for 2005 in the IEA PVPS countries was reported to be 1 500 MW, up from 1 109 MW in 2004, or an increase of 35 %. In reality global growth is even stronger since production is also increasing rapidly outside the area covered by the reporting countries. The largest growth in absolute numbers took place in Japan (220 MW) and Germany (143 MW). However, the growth rate in Germany (72 %) outpaced the rate in Japan (36 %).

Japan is the leading producer of cells (824 MW) and modules (773 MW). Production of cells and modules in this country accounted for 55 % and 50 % respectively of the IEA PVPS countries' production in 2005, with Germany in second place with 23 % and 18 % of production respectively. The Japanese producer Sharp maintains its lead. However, the

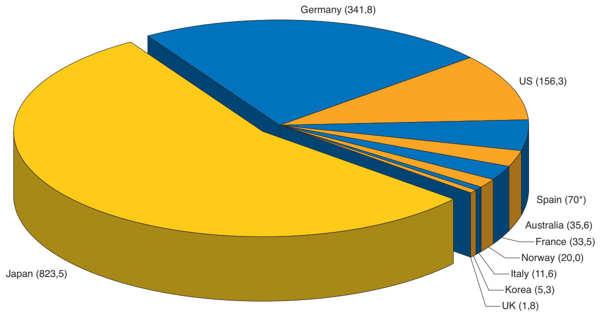

Figure 4 – PV cell production (MW) by country in 2005

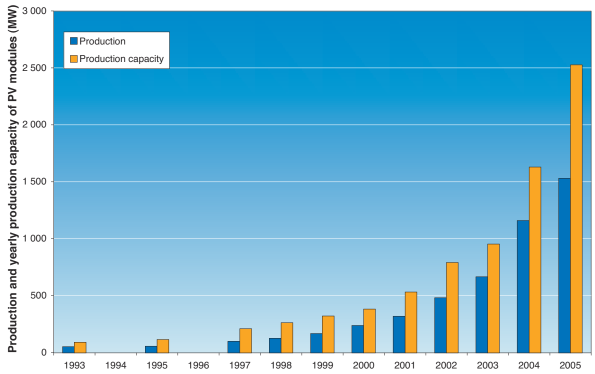

Figure 5 – PV module production and yearly module production capacity in the reporting countries (MW) between 1993 and 2005

German producer Q-Cells has advanced to the second position, before Kyocera, and Sanyo has now advanced to the fourth position. In the United States, the third largest producing country, production of cells and modules increased by 13 % and 42 % respectively from 2004. However, US output of crystalline silicon cells actually decreased in 2005, while thin-film technologies saw an increased output of 25 MW, up 109 %.

The production capacity, defined as the maximum output of a manufacturing facility, for cells increased by 91 % in Europe (mainly in Germany) and by 65 % in Japan in 2005. The worldwide capacity gain was 66 %. The increase in capacity is significantly larger than the increase in output as a consequence of the new capacity coming online. Utilization, down from 86 % in 2004 to 70 % in 2005, has been affected not only by part-year production and teething troubles, but also by lack of wafers.

Outside the IEA PVPS countries and continuing the trend reported in 2004, both China and Taiwan consolidated the significance of their contribution to global PV production with further strong growth in 2005. Although industry analysts show some disagreement over individual companies' production figures, there is fairly close agreement on the total cell production from China, at approximately 150 MW. Cell production capacity in 2006 has been estimated to exceed 500 MW. Taiwan further increased its cell production, with 2005 output up by over 70 % to 60 MW. The Philippines and Thailand together delivered a further 23 MW of cells in 2005.

The plans for expansion in 2006 amongst the reporting IEA PVPS countries are relatively modest, but become more ambitious further into the future. The current tightening of supply of silicon feedstock makes short term expansion a high risk proposition for many PV cell and module manufacturers.

Commentary – In 2005 the tightening of supply of silicon has impacted, and will continue to impact, the downstream industry in interesting ways. A number of cell and module producers are struggling and show poor capacity utilization due to their inability to secure wafers and cells. On the other hand, companies with more robust arrangements throughout the supply chain are reaping the benefits of the dynamic German market and higher prices for products. Supply / demand tensions simply serve to intensify the natural business tendencies towards both vertical integration and horizontal aggregation, where these are possible.

While about 94 % of the PV modules produced in 2005 in the countries covered by this survey were based on crystalline silicon technologies, new technologies show interesting trends:

- In the United States production of crystalline silicon cells decreased in 2005. The entire increase in production was due to thin film technologies. Over half the world output of thin film cells in 2005 came from the United States.
- Producers of high efficiency cells appear to be gaining an advantage in the currently constrained feedstock situation since their products require less silicon per watt than the conventional single and multicrystalline silicon cells. Sanyo Electric has advanced quickly as a cell and module producer based on its 17,5 % efficiency HIT (hetero junction with intrinsic thin layer) cells. The US producer SunPower is promoting 20 % efficiency back-contact cells (manufactured in the Philippines).
- A number of the reporting countries describe R&D programmes targeting new materials, both organic and inorganic, and thin film technologies.

Another interesting observation is the industry globalization trend with various national cell and module manufacturers also starting to locate in low-cost and other countries. Examples include, but are not limited to:

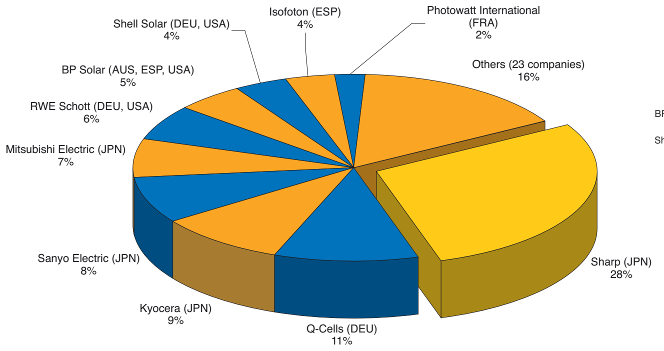

Figure 6 – Share of PV cell production by company in 2005 (%)

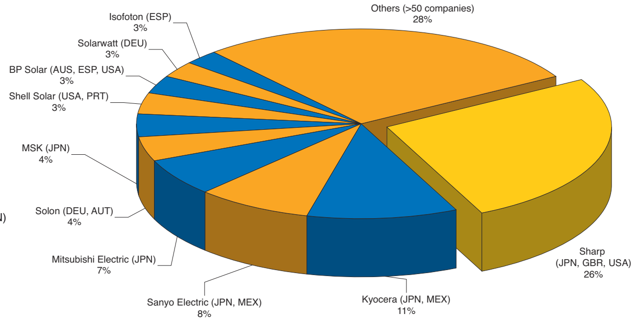

Figure 7 – Share of PV module production by company in 2005 (%)

- SunPower's (US) investment in the Philippines for production of high efficiency back-contact cells
- A total of three new module assembly plants (including big players Kyocera and Sanyo) in Mexico, based on the traditional export manufacturing system of this country (all materials coming from abroad, all products being exported)
- Kyocera's and Schott Solar's module manufacturing plants in the Czech Republic, and Sanyo's in Hungary
- Kyocera's and BP's module manufacturing in China
- Sharp's module manufacturing plants in the UK and the USA

Commentary – During 2006 and 2007 the consolidation of the industry working with crystalline silicon cells, representing 94 % of the PV market volume, is expected to continue. As previously noted, companies being in control of the supply of feedstock and wafers will have the upper hand in this process. However, 2006/2007 may also see the early signs of a long-awaited manufacturing comeback for thin-film technologies.

Domestic module production outside the IEA PVPS countries is expanding but is challenging to report accurately. Due to the sheer number of PV companies emerging in China it is difficult to definitively state the total Chinese module production. Depending on the source, China's total module production in 2005 is reported as anywhere between 260 MW and 400 MW. However, based on known cell and module production in IEA PVPS countries, coupled with the limited cell production outside of the IEA PVPS countries, even the lower of these figures appears to be considerably optimistic, perhaps by as much as 80 to 100 MW. India's total module production was largely unchanged compared to 2004, although module production capacity expanded by close to 80 %. Thailand delivered about 12 MW of modules in 2005 from two plants

2.3 Balance of system component manufacturers and suppliers

From a cost perspective, balance of system (BOS) components (the components that are not the PV modules) account for between 20 % (grid-connected) and 70 % (off-grid) of the total PV system installation costs. Accordingly the production of BOS products has become an important sector within the wider PV industry.

Particularly with the rapid expansion of the worldwide market for grid-connected PV systems, inverters are currently the focus of interest and manufacturers of PV inverters for these applications again reported impressive growth rates in 2005.

In Europe the large manufacturing companies are located in Germany, Austria, Switzerland, Denmark and the Netherlands and sell their products predominantly in the German, Italian and Spanish markets. Also in 2005 new companies entered the market for grid-connected inverters. About 40 companies are estimated to be active in this field within Europe, with German SMA Technology AG as the leading player.

Outside Europe extensive activities in this field are reported from Japan, the USA, Canada and Korea. It is likely that more than 20 companies are producing grid-connected inverters in these countries. The leading companies are Sharp, Sanyo Denki and Xantrex.

Today most of the BOS products are dedicated to the residential PV market, with typical system sizes from 2 kW up to 10 kW. However, with the increasing number of MW scale systems being installed in some countries, inverters have been developed with capacities up to 1 MW. In this context, an important activity reported from Japan is the standardization and mass production of inverters of 10 kW and 100 kW suitable for larger systems ranging up to 1 MW.

Contrary to the price trends observed for PV cells and modules, inverter prices fell significantly in 2005. Prices for grid-connected units were reported in the range from 0,6 USD/W up to 1,2 USD/W, with the lowest figures being reported in Europe.

Building integrated PV (BIPV) is of interest to a number of building companies (such as glass, façade construction and roofing materials industries) in the reporting countries. These companies are increasingly complementing their range of building products with new and innovative BIPV products.

In addition to basic BOS components such as inverters, charge controllers, support structures and storage batteries, the production of specialized components such as connectors, switchgear and monitoring systems has become an important business. Further, the production of specialized equipment for the PV manufacturing industry is a focus for a number of companies. Products in this field include chemical and gas supplies, waste recycling, abrasives and wire saw equipment for cutting wafers, pastes and inks for cells, encapsulation materials for modules and specialized measurement equipment for use in the production process.

2.4 System prices

Reported prices for entire PV systems vary widely (Table 6) and depend on a variety of factors including system size, location, customer type, connection to an electricity grid, technical specification and 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.

On average, system prices for the lowest price off-grid applications are double those for the lowest price grid-connected applications. This is attributed to the fact that the latter do not require storage batteries and associated equipment.

In 2005 the lowest system prices in the off-grid sector, irrespective of the type of application, ranged from about 10,0 USD to 20,0 USD per watt. The large range

Table 6 – Indicative installed system prices in selected countries in 2005

Country	Off-grid (per W)				Grid-connected (per W)			
	<1 kW		>1 kW		<10 kW		>10 kW	
	EUR	USD	EUR	USD	EUR	USD	EUR	USD
AUS	13,6	16,8	11,7	14,5	6,2–8,7	7,6–10,7	6,2	7,6
AUT	15,0	18,5	10,0–20,0	12,3–24,7	5,0–6,0	6,2–7,4	5,0 – 5,5	6,2–6,8
CAN	10,0	12,3			6,7–8,3	8,3–10,3	8,4	10,4
CHE	9,7–13,0	12,0–16,0	7,8–9,7	9,6–12,0	5,5–7,1	6,8–8,8	4,7–5,8	5,8–7,2
DNK	9,5–12,2	11,7–15,0	20,3–27,0	25,0–33,3	4,5–10,8	5,5–13,3	6,7–13,5	8,3–16,7
DEU					6,0	7,4		
FRA	15,0–24,0	18,5–29,6	12,0–21,0	14,8–25,9	6,5	8,1	4,5	5,6
GBR	8,1–14,0	10,0–17,3	8,1–14,0	10,0–17,3	6,9–22,4	8,5–27,6	5,0–15,5	6,2–19,1
ISR	8,1	10,0	>8,9	>11,0				
ITA	12,0–15,0	14,8–18,5	12,0–14,0	14,8–17,3	6,0–8,0	7,4–9,9	5,5–7,0	6,8–8,6
JPN					4,9	6,0	5,3	6,6
KOR	17,4	21,5	15,8	19,5	7,8	9,6	7,8	9,6
MEX	10,0–13,4	12,4–16,5					5,6	6,9
NLD					5,5–6,0	6,8–7,4	4,8	5,9
NOR	12,6–18,9	15,5–23,3			10,0–13,9	12,4–17,1		
SWE	10,9	13,4			6,0	7,4	5,4	6,7
USA	9,7–20,3	12,0–25,0	9,7–16,2	12,0–20,0	5,7–8,1	7,0–10,0	5,3–7,3	6,5–9,0

Notes: 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.
More expensive grid-connected system prices are often associated with roof integrated slates or tiles or one-off building integrated designs or single projects (eg DNK, GBR, NOR), and figures can also relate to a single project (eg CAN, MEX). ISO country codes are outlined in Table 12.

of reported prices is a function of country and project specific factors. As in 2004, the average of these system prices is about 13,0 USD per watt.

The lowest achievable installed price of grid-connected systems in 2005 also varied between countries as shown in Table 6. The average price of these systems was 6,5 USD and 6,6 USD per watt in 2004 and 2005 respectively. Similar to 2004, the lower reported prices in 2005 were typically around 5,5 USD to 6,5 USD per watt.

Large grid-connected installations can have either lower system prices depending on the economies of scale achieved, or higher system prices where the nature of the building integration and installation, degree of innovation, learning costs in project management and the price of custom-made modules may be significant factors.

Photovoltaic modules continue to make up about two-thirds of the lowest achievable grid-connected system prices that have been reported. In 2005 the average price of modules in the reporting countries was around 4,5 USD/W, an increase of less than 5 % over the corresponding figure for 2004. Table 7 shows the change in module (current) prices in some of the reporting countries from year to year.

Interestingly, a number of countries reported a decrease in module prices from 2004 – Canada, Japan, and Korea – while other countries reported almost no change – Australia, Austria, Denmark and the UK. It is worth noting that the widely discussed increase in module prices was largely a European phenomenon in 2005, possibly due to the local pressures on demand.

It is also worth noting that, with respect to long-term trends, learning curve theory suggests that the average price of modules in the IEA PVPS countries should have decreased by about 8–10 % since 2004 with the total market size currently doubling in two years.

Figure 8 and Figure 9 show the evolution of normalized and actual prices respectively for modules and systems, accounting for inflation effects, in selected key markets.

Table 7 – Indicative module prices in national currencies per watt in reporting countries

Country	Currency	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005		
																EUR	USD
AUS	AUD			7		8		8	8	8	8	7	7	8	8,0	4,9	6,1
AUT	EUR											4,5	3,1–3,2	3,6–3,7	3,6–3,9	3,6–3,9	4,4–4,8
CAN	CAD								11,09	10,7	9,41	7,14	6,18	5,53	4,31	2,9	3,6
CHE	CHF											7,5		4,1–4,3	4,5–4,7	2,9–3,1	3,6–3,8
DNK	DKK									40	40	33	21–45	30–50	30–50	4,1–6,7	5,0–8,3
DEU	EUR	5,98	5,93	5,42	4,91	4,50	4,14	3,73	3,63	3,58	3,53	3,04	2,5–9,7	3,0–9,6	4,0–6,0	4,0–6,0	4,9–7,4
ESP	EUR												2,6–4,25				
FRA	EUR				13,3								4,2	4,0	4,2	4,2	5,2
GBR	GBP										4,24	4,24	2,3–4,0	2,4–3,8	2,4–4,3	3,6–6,3	4,4–7,8
ISR	USD												5–6,3	4,5–6,1	5,4	4,4	5,4
ITA	EUR		4,65				4,13				3,9–4,7	3,5–4,3	3,1–3,9	3,0–3,6	3,2–4,0	3,2–4,0	4,0–4,9
JPN	JPY	966	950	927	764	646	656	670	600	548	484	463	446	439	431	3,2	3,9
KOR	KRW			9 400	9 400	8 200	8 500	9 200	7 500	7 100	7 200	7 200	7 000	6 500	4 600	3,6	4,5
MEX	MXP												65	68–80	73–85	5,4–6,3	6,7–7,8
NLD	EUR			9,5	7	7,5	6	5	4,75	4,73	4,73	4,62	4,5	3,5–4,5	3,8–5,0	3,8–5,0	4,7–6,2
NOR	NOK												55–100				
PRT	EUR										4	3,5	3,5	3,5–4			
SWE	SEK												26–70	26–70	32–70	3,5–7,6	4,3–9,4
USA	USD	4,25	4,25	4,00	3,75	4,00	4,15	4,00	3,50	3,75	3,50	3,25	3,0	3,5	3,6	2,9	3,6

Notes: Current prices. ISO country codes are outlined in Table 12. ISO currency codes are outlined in Table 12.
Single figures generally refer to 'typical' module prices; where there is a wide range in the figures presented for a given country, the lower value generally represents the lowest price achieved & reported (often for a large order) whereas a significantly higher figure can refer to special products, roof tiles etc. Details are contained in the individual national reports.

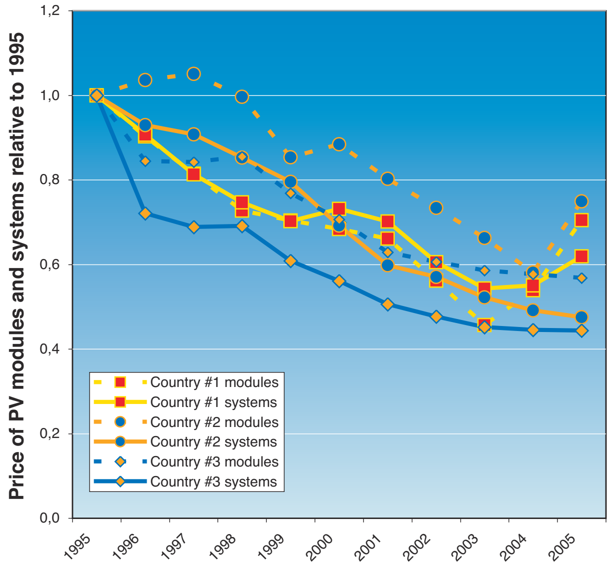

Figure 8 – Evolution of price of PV modules and systems in selected reporting countries accounting for inflation effects – Years 1995–2005 (Normalized to 1995)

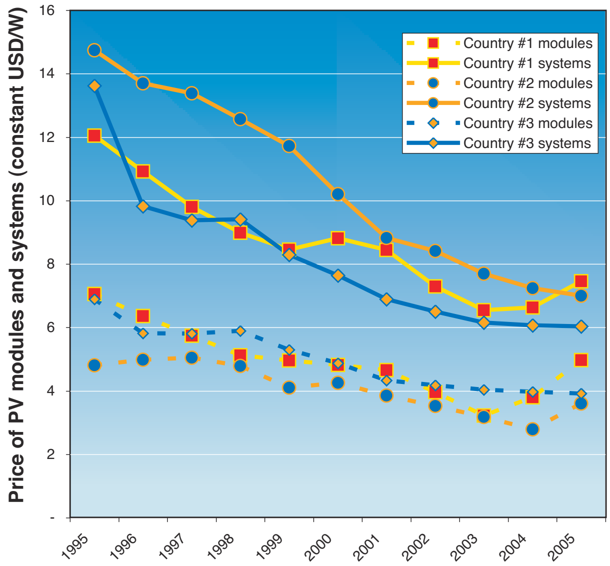

Figure 9 – Evolution of price of PV modules and systems in selected reporting countries accounting for inflation effects

2.5 Economic benefits

The dramatic growth of installed PV capacity has continued to bring significant economic benefits to some of the reporting countries and has been recorded for the second year in some of the most significant markets. Whilst it is too early to examine the data for trends, three-quarters of those countries reporting on this issue estimated that the net business value increased by over 30 % over the year. In time, this measure is expected to illustrate the increasing global production base for PV modules and components.

All countries reporting on this topic reported a positive trade balance in PV equipment. However this should be treated with some caution, as locating accurate information on the import of equipment has proved problematic.

With respect to labour places the data collected are generally more complete but again are potentially subject to more generalized estimation. Total direct employment is now reported to be at least 55 000 persons across research, manufacturing, development and installation, and has increased by around 17 % compared to 2004. The majority of this increase has been within Germany and Japan, but Denmark, France, Switzerland and Austria also showed significant increases related to the implementation of specific programmes during 2005. The trend for labour intensive manufacturing activities, such as module assembly, to move to low cost base economies continues and has been discussed in section 2.2. Many manufacturing companies in Europe have continued to benefit from the strong level of demand within Germany, even when their domestic markets have diminished due to the ending of specific programmes.

3 Policy and regulatory 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

Table 8 highlights the key initiatives reported in the participating countries during 2005. The main fiscal instruments being used to publicly support or promote PV in the IEA PVPS countries continue to be the direct capital subsidies and the enhanced feed-in tariffs. In practice, public support can involve a combination of measures and will usually function more effectively when this is the case. Funding issues are significant and are critical to the success of any mechanism.

Various forms of tax credits appear to be emerging in a number of countries as an attractive support measure.

Also, as the PV market matures and opportunities for business are identified, various non-utility as well as utility-based commercial initiatives are emerging. These include activities such as preferential home mortgage terms and green loans from commercial banks, share offerings in private PV investment funds plus other schemes that all focus on wealth creation and business success using PV as a vehicle to achieve these ends. These types of measures will be surveyed and discussed in subsequent editions of the Trends report.

Table 8 – Initiatives and perceptions in reporting countries

	New Initiatives and Promotional Activities	Utility and public perceptions
AUS	*With the running down of the existing market support mechanisms (PV Rebate Programme & Renewable Remote Power Generation Programme) the Solar Cities initiative is driving strong interest in sustainable energy, and PV in particular, throughout new sectors such as financial services and local governments. The Commonwealth Government is currently evaluating the bids made by eleven consortia for a seven year funding budget of 75 million AUD. Out of these only four will be successful, but it is expected that the interest generated by the competition will lead to other deployment strategies even in those that did not secure funding from this source. There will also be opportunities for new R&D in the context of three new programmes that aim to support Australia's technology lead in remote power systems. In particular, the Renewable Energy Development Initiative (REDI) has already supported the commercialization of cell technology and a programme addressing advanced electricity storage technologies seeks to overcome intermittency issues in electricity supply.*	*Rapid growth in peak electricity demand and high oil costs dominate the planning debate at present. And whilst the peak demand increases are strongly linked to increased air conditioner use, there has been little interest in incentives that may link this trend with PV benefits. Plans are also underway to replace the current seven regulators with a single national authority that should encourage a more standard level of regulation in future. This may in turn lead to a more strategic approach to PV. The roll-out of interval meters to all consumer groups will lead to a higher recognition of the value of daytime (peak) generation but currently it is uncertain if utilities will be in a position to recognize this value in their distributed generation purchase prices.*
AUT	*The discontinuity in the market left by the 15 MW capacity cap for feed-in tariffs has continued to be filled by capital support grants from three (of the nine) Austrian provinces, which have had a limited and variable response.* *A commercial initiative by a "green" utility offers net metering contracts which, whilst not very attractive on their own, when combined with a provincial government capital grant have proved an attractive investment incentive.*	*Utility and public perceptions of PV are excellent but enthusiasm has only extended to investment when substantial financial support is available. For utilities, the connection of small embedded generation is routine and grid management is not reported to give much concern.*

Table 8 – continued

CAN	*The Climate Change Plan for Canada launched in 2005 combines regulatory, negotiated and incentive based approaches to meeting the country's targets on climate change. Within the context of this plan the programme 'Project Green' sets to combine efforts of all stakeholders. One of the first projects launched under this action is a series of zero energy demonstration residences. The vast majority of PV capacity is installed on a purely commercial basis for off-grid applications.*	*Resistance still endures to grid-connected PV applications from utilities, building inspectors and unions who continue to perceive a health and safety risk. However, a new umbrella organization – Power Connect – aims to work with all stakeholders with interests in distributed generation to provide regulatory and technical support to enable this type of generation to thrive in a competitive energy market. The public perception of PV remains that it is only a suitable technology for limited off-grid applications.*
CHE	*A revision of the Federal Electricity Act currently passing through the legislature will set out energy policy objectives that will promote hydropower and other renewable energy sources. In particular a feed-in tariff system for all renewable technologies has been proposed, funded from a levy on the high voltage grid. Whilst this proposal still has to progress through the political process, it does offer the potential for a substantial level of new interest in the sector from 2008.*	*Utilities have experience of the grid connection of PV, with some taking an increasing interest in the opportunities in their region. There will be a continued national debate over energy policy as the Federal Electricity Bill passes through the political process. However, how support for sustainable energy systems fairs against the background of growing concerns over energy security and price stability has yet to be seen.*
DEU	*Strong demand continues to be driven by feed-in tariff arrangements and is complimented by specific programmes in the Federal States and utility demonstration or pilot systems. In energy research, alongside the existing Fourth Programme, a Fifth Programme (2006 – 2008) will seek to examine production, cost reductions and considerations of environmental issues in manufacturing and operation of PV.*	*Connections to the grid are seen as routine and many utilities participate in the PV market. Public knowledge and perception of PV are high, mainly as a result of the high numbers of distributed grid-connected systems installed.*
DNK	*With the publication of a new national energy plan in 2005, new targets have been set for the contribution of renewable energy to the national supply, but no specific measures are proposed for PV. However, a PV strategy is being finalized that draws together the fields of research, development and demonstration. The SOL-5000 initiative which aims to reduce the need for investment incentives continues to be developed and will target 5 MW over 7–8 years. The series of interim net-metering schemes finally became permanent in late 2005.*	*The Danish utilities exhibit a growing interest in PV as a future business area. Their focus is on small roof-top systems that include modular do-it-yourself systems in the range of a few hundred watts. The first DIY kits were finally approved for sale in 2005 in the context of the SOL-1000 project. There continues to be a strong social interest in the technology, with a limited number of consumers willing to pay the full generating costs by purchasing PV electricity from the Copenhagen Energy's 'green tariff' offering.*
FRA	*2005 was marked by significant initiatives that strengthen the legal, regulatory and financial position of PV in France. These include: an Energy Framework Policy Law which strengthens energy management and application support; new R&D programmes from an enhanced research agency structure; a new 40 % tax credit for private PV installations (raised to 50 % in 2006); and significantly enhanced feed-in tariffs: 0,30 EUR/kWh (plus 0,25 EUR/kWh premium in 2006 for BIPV projects). In 2005 the real impacts of the tax credit and the enhanced feed-in tariffs were difficult to assess. The new research structure has already lead to strong stimulation in research proposals as there are now two agencies (ADEME and ANR) administering RTD funds in 2005.*	*EDF, the main French electricity utility, continues to be active in the development of publicly funded off-grid systems, the development of standards for PV and the development of CIGS PV modules. The more attractive financial basis for private PV installations is likely to lead to greater public levels of technology awareness as installations progress*

Table 8 – continued

GBR	*Funding for the new UK Government Low Carbon Buildings Programme was announced during 2005. The new programme replaces the Major Demonstration Programme and will provide grants for micro generation technologies including PV for householders, community organizations, schools, the public sector and businesses. The UK-wide scheme aims to demonstrate how energy efficiency and small scale renewables will work together to create low carbon buildings. Minimum energy efficiency standards must be met before applying for a grant. Up to 50 % funding will be available from Spring 2006 for new PV projects, subject to maximum levels per kW. Larger projects will compete for funding in quarterly funding rounds.*	*All UK Distribution Network Operators (DNOs) have experience of PV systems. Due to the low-level of PV penetration in the UK, the DNOs do not see solar electricity as a business priority at this time. Nevertheless, there is a general interest in PV issues, particularly by the DNOs in the south of the country where PV systems are more common, and all DNOs are keeping a watching brief to see how the sector develops.*
ISR	*In principle, legislation now allows all private electricity plant to connect to the grid and export all their excess generation, although the detailed regulations and terms are not yet formulated. The legislation also allows for a premium price to be paid for export, based on calculations that take account of the pollution avoided. Additionally efforts continue to allow small (<20 kW) generators to connect via a simplified procedure and receive the benefits of the time-of-day tariff structure without the need for the purchase of a second (export) meter.*	*The state utility, IEC, is reported to be reluctant to cooperate and coordinate efforts to allow private generators using any technology to connect to the grid. Public awareness of PV is high but it is normally associated with off-grid applications and is generally perceived to be a high cost source of electricity for all types of projects.*
ITA	*The introduction of the feed-in tariff programme in the second half of 2005 was enthusiastically taken up, with over 266 MW of capacity already applied for up to the end of 2005. In response to this the objective limit of 500 MW by 2015 was raised to 1 000 MW in early 2006. For plants over 50 kW a tender system is in place which favours tariff competition. The tariff is available on the whole of the electricity generated by the PV plant (and not just the exported power).*	*Several national and local utility companies continue to support the implementation of distributed grid-connected generation, co-operating with national agencies and research institutes and industry to overcome technical barriers. In particular cooperation with respect to grid interfaces has helped to reduce the cost and delay associated with grid-connection. Following this work grid-connection is now considered routine. The number of, and enthusiasm with regard to, applications submitted for the feed-in initiative demonstrates the sharply increasing level of public interest in the sector.*
JPN	*No new promotional activities were started in 2005 and the main residential programme drew to a close after 12 years of successful activity. Attention is now focused on the promotion of PV in non-residential facilities, with the trend being towards systems with a capacity of 10 kW or over. The main purposes of the current field test 'Field Test Project on New Photovoltaic Power Generation Technology' are to promote further introduction of medium and large-scale PV systems with capacities greater than 10 kW, improve the performance and reduce the cost by adopting new technologies.*	*Utilities have demonstrated strong leadership in supporting PV expansion through voluntary net metering arrangements (since 1992), the introduction of a 'Green Power Fund' to support projects on mainly community facilities, and by enthusiastic activity to ensure they met the requirements of the renewable portfolio standard assigned to them in 2003. PV is supported strongly by the general public, with residential sales of PV continuing even after the end of the main residential subsidy programme. Additionally, commercial and industrial interest is growing under the umbrella of the new dissemination programmes.*
KOR	*Backed by a new energy policy, specific actions are now being planned to deliver up to 1,3 GW of installed PV by 2012. These include: the implementation of a feed-in tariff which is guaranteed for fifteen years; a requirement that all new public buildings over 3 000 m^2 must have a renewable energy facility that represents 5 % of the construction budget; and capital and other incentive schemes aimed at all sectors.*	*Utilities and the general public have had limited exposure to PV, although the impact of publicity surrounding Government programmes is starting to raise awareness.*

Table 8 – continued

MEX	*In late 2005 a bill started its progression through the political process that aims to strongly encourage the use of renewable energy resources. Although no specific programmes are proposed for PV, there are elements that would aid its wider implementation. In particular, the bill proposes: guaranteed take-up by the utility of intermittent renewable resources; a Green Fund to support technologies that are not currently cost competitive; and a fund to support remote rural electrification with renewable resources. Recent studies on the costs of rural electrification have shown that PV represents the least cost option in many communities in the southern regions of Mexico.*	*As a result of increasing interest in grid-connected PV, the national utility has initiated work by the Electrical Research Institute to develop the requisite connection codes for systems up to a maximum capacity of 30 kW. Currently the vast majority of applications are for off-grid remote domestic and commercial applications.*
NLD	*For photovoltaic solar energy the government mainly sees a role in the longer term, after 2010. Therefore the government does not specifically support the implementation of PV, but rather focuses on research and development aimed at PV cost reduction in the longer term.*	*Both public perception and utility familiarity with PV are high, but the current realities in the market largely reflect the government position of PV being a technology for the future.*
NOR	*Apart from a general investment subsidy of up to 25 % available to a range of renewable energy technologies, there are no specific support measures. High profile projects – such as the new Opera house in Oslo – are seen as one-off demonstrations of national environmental consciousness. Off-grid projects are developed on a purely commercial basis.*	*Some utilities have made selective investments in remote areas and but are increasingly exposed to measures such as greenhouse gas emission trading and the grid connection of other variable generation, such as wind power. The majority of public perception is on the use of PV in vacation cottages, although continued high environmental taxation on domestic electricity has elevated the energy debate.*
SWE	*The implementation in May 2005 of the investment subsidy programme, a tax credit (of up to 70 %) of the capital cost of PV installations placed on buildings used for public purposes, is a significant market deployment measure for Sweden. The expenses eligible for funding include all external costs incurred in delivering the project and the credit is capped at a maximum of 5 million SEK per building. Interest has been strong with 42 applications made by the end of 2005 for projects between 2 and 80 kW, and represents around one third of the total budget for this measure.*	*Public perceptions are clouded by the misconception that PV is unsuitable for the Swedish climate, apart from vacation cottages in remote locations. The investment subsidy programme has already raised awareness with sectors which have not necessarily had exposure to PV previously. The attitude of utilities varies – some are generally positive to PV, being involved in research and demonstration projects, with others not showing much interest. The cost of connection and metering requirements remain contentious issues in some situations.*
USA	*The existing structure of State government support has been supplemented by a Federal PV Tax Credit which will apply from 2006 – 2008. This provides a 30 % tax credit for both residential and commercial systems, although the support available to the residential sector is capped at 2 000 USD per system. Programmes in California continue to be the most diverse and far reaching, but new programmes in New Jersey, New York and Arizona are expected to have considerable impact when combined with the Federal Tax Credit. There are a variety of programmes in other states, some of which target particular sectors (e.g. schools), and that use a combination of renewable portfolio standards, direct subsidy and tax credits.*	*The deregulation of the electricity industry in the USA is proceeding and all states are required to permit the free trade in generation, distribution and service. This process has resulted in several outcomes that may be beneficial to the expansion of PV. Some states have required initiatives such as green pricing, renewable portfolio standards, net metering and simplified connection requirements. However, as each state is developing their own legislative structure, the programmes coming forward are extremely diverse. In general, utilities can now see the potential benefits of a large and growing independent power sector but their perception of the potential of PV – outside of California – remains low.*

3.2 *Indirect policy issues and their effect on the PV market*

Many governments turning their attention to longer-term approaches to climate change and energy security issues are implementing or considering the regulatory approach commonly referred to as the 'renewable portfolio standard' (RPS) to increase renewable energy deployment in their countries. However, in the absence of a national strategy for PV or at least some concrete targets for installed capacity of PV, the RPS is unlikely to have a positive impact on PV deployment and may even have unforeseen negative implications (Table 9).

However, in the United States in particular, a number of PV-specific state regulatory approaches have emerged, due in part to 'regulatory competition' between the multitude of entities responsible for electricity utility regulation in the 50 states, their history and public interaction and also the diversity of the electricity sector (more than 3 000 public and private electricity utilities). Notable amongst these RPS are the following: the Arizona Environmental Portfolio Standard requires a 60 % PV contribution to the required RPS renewable energy mix in the 2004-2012 period, and if sustained could lead to 100 MW installed PV capacity by 2007; the Colorado Renewable Energy Standard requires a 4 % PV contribution to the renewables mix, with half of this to be located on-site at customers' facilities; New Jersey requires 2,12 % PV contribution to its total electricity supply by 2021; Pennsylvania and the District of Columbia also have PV 'set-asides'; New Mexico, Nevada, Maryland and Delaware provide additional credit for energy provided by PV systems. More details about state and local incentives can be found in the Database of State Incentives for Renewable Energy (DSIRE) at http://www.dsireusa.org .

Other regulatory measures to promote renewables reported by participating countries include disclosure on electricity bills, tradable certificates, and branding and labels, although their application is not widespread.

Within the electricity utility sector different business models of PV promotion are emerging, partly in response to public policy and regulation and partly to realize business opportunities. There are a number of 'green power' schemes offered by electricity businesses (Table 9), 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. Electricity businesses also have an opportunity to maximize network benefits and promote other benefits when they support or invest in projects that will form part of their green power scheme. However green power schemes especially in their infancy are often characterized by the same problems for PV seen in the government-driven RPS approaches.

However, as with the RPS approach, a number of PV-specific approaches have emerged – partly in response to a particular utility's approach to its customers and PV, and partly as a function of market diversity and competitive pressures.

Copenhagen Electric (Denmark) continues to sell certified PV electricity since 2003, with the scheme reporting small but growing success even though the end-user cost of the certified PV electricity is 3–4 times that of standard electricity. The utility contracts to buy all electricity from new PV systems for the next 20 years at commercial terms and then sells PV electricity to consumers in small standard packages. In the United States a number of utilities are offering their customers the opportunity to purchase PV electricity specifically – details can be found at the US Department of Energy's 'The Green Power Network' website http://www.eere.energy.gov/greenpower. Included amongst these utilities' programmes are: the Arizona Public Service 'Solar Partners Programme' based on centralized PV; the UniSource Energy Services 'Greenwatts' programme, also in Arizona; Florida's City of Tallahassee / Sterling Planet 'Green for You' Programme and Utilities Commission City of New Smyrna Beach 'Green Fund'; Muscatine Power and Water's 'Solar Muscatine' programme; and Austin Utilities, Owatonna Public Utilities and Rochester Public Utilities 'SolarChoice' programme based on electricity from local PV systems. In Australia, electricity utility Origin Energy (also a PV manufacturer) offers 'GreenEarth Solar', a 100 % PV electricity green power product.

PV electricity sales contracts can also be used to leverage customer loyalty by electricity utilities. For example, under the 'Solar-Partnership' programme offered by the Green Electricity Company in Austria, customers who have an electricity purchase contract with that particular company are awarded a preferential tariff for the energy produced by their own PV installations.

Table 9 – Key market support measures: some observations and conclusions – an update

	Enhanced feed-in tariffs	Direct capital subsidies	Green electricity schemes	Renewable portfolio standards
Target audience	Grid-connected PV customers with business cash flow requirements eg housing developers, investors, commercial entities.	PV customers with limited access to capital eg households, small businesses, public organizations.	Residential and commercial electricity customers.	Liable parties, typically the electricity retailing businesses.
Countries reporting use of this support measure, or similar	Austria, France, Germany, Italy, Korea, The Netherlands, Spain	Australia, Austria, Denmark, France, Germany, Japan, Korea, The Netherlands, Sweden, Switzerland, UK, USA	Australia, Denmark, Switzerland, USA	Australia, Austria, Japan, Sweden, USA
Implementation	Typically administered by the electricity industry billing entity.	Requires considerable public administrative support to handle applications, approvals and disbursements.	Commercial business operation of the electricity utility; some public administrative support for accreditation of projects.	Public administrative support via a regulatory body.
Economic and political considerations	Method of internalizing the externalities associated with traditional energy supply	Up-front capital cost is seen as the main economic barrier to the deployment of PV. Can be used for both off-grid and grid-connected support programmes.	The 'good public policy' aspect of government involvement in selective, customer-driven, electricity business commercial activities raises some interesting questions. Utility projects may better realize the network benefits of PV.	Can be seen as a distortion in the functioning of the electricity market, especially if overly prescriptive.
	There are varying political perceptions regarding the use of public funds or funds generated by the electricity industry.			
Potential effectiveness	Function of the size of the enhancement.	Can be very effective as a simple but blunt approach to deployment – but not necessarily cost-effective.	Becoming commonplace and well understood with regard to renewables in general.	
Problems	Less predictable where specific results, such as limited capacity installed or rates of deployment are being sought. Can result in overheated markets on the one hand if rates are too high, but also to negligible impacts if rates are too low.	Often seen as too simplistic and not encouraging broader consideration of customer energy usage or willingness to pay for PV. Also criticized for inflating system prices and subsidizing more affluent consumers.	Less predictable where specific results are being sought. Unless PV specific, usually characterized by a broad, least-cost approach favouring hydro, wind and biomass.	The general requirement for renewable energy may simply encourage the lowest direct cost renewable energy options (and not PV) for consideration by the liable parties.
Solutions	Clearly target this approach on specific, limited market segments.	Explore willingness to pay and social equity issues. Clearly reduce subsidy rate over a period of time.	Encourage / create demand for PV specific electricity.	Consider a portfolio approach to the RPS, or at least PV specific measures.
Examples of PV-specific approaches reported in national reports			Copenhagen Electric – sale of certified PV electricity, reporting a small but slowly growing success.	

3.3 Standards and codes

For 25 years the Technical Committee (TC) 82 of the International Electrotechnical Commission (IEC, www.iec.ch) has been the main promoter of worldwide standardization in the field of PV. Established in 1981, TC 82 has been preparing international standards for "systems of photovoltaic conversion of solar energy into electrical energy and for all the elements in the entire photovoltaic energy system". As of the end of 2005, 29 IEC International Standards and 6 Technical Specifications have been published covering a comprehensive range of issues. Currently 23 countries are active participants in TC 82 and a further 13 have observer status.

The main work on new and revised standards is carried out within six individual working groups (WG) consisting of experts dealing with issues ranging from Glossary to Balance-of-system components. Further cross-cutting issues such as Rural Electrification or Batteries are handled by a Joint Working & Coordination Group (JWCG) of experts from different TCs. Conformity assessment and certification are now treated within the framework of the IECEE (Worldwide System for Conformity Testing and Certification of Electrical Equipment).
2005 was an active year for TC 82 with the publication of 5 new or revised International Standards or Technical Specifications (TS):

- Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval (IEC 61215 Ed. 2.0 2005-04)
- Balance-of-system components for photovoltaic systems – Design qualification natural environments (IEC 62093 Ed 1.0 2005-03)
- Recommendations for small renewable energy and hybrid systems for rural electrification
  - Part 4: System selection and design (IEC/TS 62257-4)
  - Part 5: Protection against electrical hazards (IEC/TS 62257-5)
  - Part 6: Acceptance, operation, maintenance and replacement (IEC/TS 62257-6)

Currently on top of TC 82's agenda are revisions to the IEC 60904 series, which define fundamental requirements such as measurement principles for photovoltaic devices. Many of these standards date back to the late 1980's or early 1990's and need to be revised and amended. Additional topics, some of which had already been on the list for some years, concern documents relating to the power and energy rating of PV modules, safety of converters and charge controllers for PV systems. WG 7, PV Concentrators, has developed a draft standard for the design qualification and type approval of concentrator PV modules following the already existing standards for silicon crystalline and thin film PV modules.

On the European level the CLC/TC 82 of the European Committee for Electrotechnical Standardization (CENELEC) aims to support market development by harmonization of standards. In this context CLC/TC 82 closely cooperates with its counterpart, the IEC TC 82 as well as the national committees. In areas where there are specific European concerns, CLC/TC 82 is also developing its own standards. Currently, these projects focus on crystalline silicon wafers and PV cells, for which a draft has recently been prepared. Projects are currently underway dealing with performance assessment and data sheet requirements for grid-connected PV inverters as well as BIPV.

In the USA standardization focuses on safety and interconnection issues of PV systems. Under the framework of the US DOE National Photovoltaic programme a portion of the standards, codes and certification activities are supported and funded. US representatives also actively participate in the IEC TC 82. In the field of certification and conformity assessment US activities include hardware and practitioner certification programmes such as the draft test protocol for performance certification of inverters for PV applications, headed by the Sandia National Laboratories. In 2005 the California Energy Commission (CEC) adopted the main part of the protocol to provide inverter certification for its Emerging Renewables programme. The 'Voluntary Practitioner Certification Programme' also continued during 2005 as a single national programme, headed by the North American Board of Certified Energy Practitioners (NABCEP).

In Japan, the Japanese Standards Association together with Japan Electrical Safety and Environment Technology Laboratories (JET) is very active in the field of PV standardization. In 2005 two new Japanese Industrial Standards (JIS) were published and 20 were reviewed or amended. Most of them are consistent with the IEC documents. JET started a programme for the certification of PV modules (JETPVm), including tests for performance and reliability of PV modules, and which at the end of 2005 covered 66 module types from 15 manufacturers. JET is also conducting a certification programme for the performance and reliability of grid-connected inverters (including the protection unit) for residential PV systems.

Although grid-connection of PV systems has been in the focus of standardization for several years, this issue remains controversial. Grid-connection is still almost exclusively addressed by national documents or utility guidelines and there is still a long way to go to achieve international harmonization in this field. Some countries have established dedicated PV guidelines which allow a smooth and easy grid-connection of PV but, despite this, the deployment of grid-connected PV is often constrained by inappropriate regulations that often cause an increase of system costs due to long delays or bureaucratic barriers.

PV GAP, the PV Global Approval Programme aims to promote globally accepted standards, testing laboratories and reference manuals for PV manufacturers with a focus on developing countries.

Based on the IECEE certification scheme a 'PV Quality Mark' for PV components and a 'PV Quality Seal' for PV systems are licensed to manufacturers if their product qualifies. However, only five companies have received approval to display the label so far. Furthermore, PV GAP has developed 14 "PV Recommended Specifications" (PVRS) in areas where an IEC standard does not exist. Between PV GAP and TC 82 of the IEC there is an official liaison to promote the global use of IEC PV Standards and extend the PV standardization process to developing countries.

PV system at Kawasaki Municipal Tama Hospital, Japan

4 Summary of trends

The countries participating in the IEA PVPS Programme have a diversity of PV production, applications and policy interests.

- The market for PV power applications continues to expand in spectacular fashion: between 2004 and 2005 the cumulative installed capacity in the IEA PVPS countries grew by 42 %, reaching 3,7 GW, with over 1 GW added during 2005. As in recent years, by far the greatest proportion in 2005 was installed in Japan and Germany alone (85 %).

- Although increasingly dominated by grid-connected applications in the reporting countries (about 95 % of the 2005 market), one third of countries report off-grid applications as their dominant market.

- The public budgets for market stimulation, research and development, and demonstration and field trials in 2005 in the IEA PVPS countries vary widely, with the total public expenditure and the breakdowns being quite similar to that for 2004 at around 1 billion US dollars.

- There are seven companies and ten plants producing feedstock silicon in four IEA PVPS countries. Outside the IEA PVPS countries the production of silicon is negligible. In 2005 about 11 000 t were sold to the PV industry. Amongst the ingot and wafer businesses, those companies having their own feedstock or having secured long term contracts are best placed to capitalize on the current high demand for their products.

- The total photovoltaic cell production volume for 2005 was reported to be 1 500 MW, up from 1 109 MW in 2004, or an increase of 35 %. The largest growth in absolute numbers took place in Japan (220 MW) and Germany (143 MW). The growth rate in Germany (72 %) outpaced the rate in Japan (36 %), however Japan remains the leading producer of cells and modules (55 % and 50 % respectively of the IEA PVPS countries' production in 2005).

- While about 94 % of the photovoltaic modules produced in the countries covered by this survey were based on crystalline silicon technologies, new technologies began to show some movement in 2005. Another interesting observation is the accelerating industry globalization trend with various cell and module manufacturers starting to locate in a number of countries. The trend from previous years of development of PV components specifically designed for building integration has continued. Inverters have become larger and cheaper.

- Photovoltaic modules make up about two-thirds of the lowest achievable grid-connected system prices that have been reported. In 2005 the average price

Table 10 – Installed PV power and module production in the IEA PVPS reporting countries

Year	**Cumulative installed power and percentage increase**						**Power installed** during year in IEA PVPS reporting countries (MW)	**Module production** during year in IEA PVPS reporting countries (MW)
	Off-grid		**Grid-connected**		**Total**			
	MW	%	MW	%	MW	%		
1992	78		31		110			
1993	95	21	42	32	136	24	26	52
1994	112	19	51	24	164	20	28	
1995	132	18	66	29	199	21	35	56
1996	158	19	87	32	245	23	46	
1997	187	19	127	46	314	28	69	100
1998	216	15	180	42	396	26	82	126
1999	244	13	276	54	520	31	124	169
2000	277	14	452	64	729	40	206	238
2001	319	15	670	48	989	36	260	319
2002	354	11	980	46	1 334	35	345	482
2003	410	16	1 418	45	1 828	37	494	667
2004	452	10	2 155	52	2 607	43	779	1 160
2005	*514*	*14*	*3 183*	*48*	*3 700*	**42**	**1 093**	**1 532**

Notes: 2004, 2005 figures no longer include Finland.
***2005 total (MW) and power installed during year (MW) include estimate for Portugal;** 2005 off-grid (MW) and (%) and grid-connected (MW) and (%) do not include Portugal.*

of modules in the reporting countries was around 4,5 USD per watt, an increase of less than 5 % over the corresponding figure for 2004. Interestingly, a number of countries reported a decrease in module prices from 2004 while other countries reported almost no change. The widely discussed increase in module prices appears to have been a largely European phenomenon in 2005, possibly due to the local pressures on demand.

- The lowest achievable installed price of grid-connected systems in 2005 varied between countries, with an average price of 6,6 USD per watt (marginally higher than in 2004). Similar to 2004, the lower reported prices in 2005 were typically around 5,5 USD to 6,5 USD per watt. On average, system prices for the lowest price off-grid applications are double those for the lowest price grid-connected applications.

- The main fiscal instruments being used to publicly support or promote PV in the reporting countries continue to be the direct capital subsidies and the enhanced feed-in tariffs. Funding needs to be stable over time, separate from political interference, transparent and clearly targeted. Various forms of tax credits are emerging in a number of countries as an attractive PV support measure. A limited number of PV-specific regulatory approaches have been developed based on the renewable portfolio standards model. Also, a small number of PV-specific approaches to electricity utility green power products are in operation – partly in response to a particular utility's approach to its customers and PV, and partly as a function of market diversity and competitive pressures. As the PV market matures and opportunities for business are identified, various non-utility as well as utility-based commercial initiatives are starting to have an impact.

Table 11 – IEA PVPS Task 1 national report authors

Australia	*Muriel Watt, School of Photovoltaic and Renewable Energy Engineering, University of NSW*
Austria	*Roland Bründlinger and Hubert Fechner, Arsenal Research*
Canada	*Josef Ayoub, Sylvain Martel and Lisa Dignard-Bailey, CANMET Energy Technology Centre Varennes, Natural Resources Canada*
Denmark	*Peter Ahm, PA Energy A/S*
France	*André Claverie, ADEME*
Germany	*Lothar Wissing, Forschungszentrum Jülich, Projektträger Jülich*
Israel	*Yona Siderer and Roxana Dann, Ben-Gurion National Solar Energy Centre*
Italy	*Salvatore Guastella, CESI Ricerca; Salvatore Castello, Anna De Lillo, ENEA*
Japan	*Osamu Ikki, RTS Corporation; Yukao Tanaka, NEDO*
Korea	*Kyung-Hoon Yoon, KIER; Donghwan Kim, Kyung Shick Yoon, KPVDO*
Mexico	*Jaime Agredano Diaz and Jorge Huacuz Villamar, Instituto de Investigaciones Electricas*
Netherlands	*Job Swens, SenterNovem*
Norway	*Lars Bugge and Fritjof Salvesen, KanEnergi AS*
Sweden	*Ulf Malm and Lars Stolt, Ångström Solar Center*
Switzerland	*Pius Hüsser, Nova Energie GmbH*
United Kingdom	*Sarah Davidson, IT Power*
United States of America	*Ward Bower, Sandia National Laboratories; Susannah Pedigo, NREL; Paul Maycock, PV Energy Systems*

Task 1 national participants and their contact details can be found on the IEA PVPS website www.iea-pvps.org . This report has been prepared under the supervision of Task 1 by Task 1 participants Roland Bründlinger, Paul Cowley, Bent Sørensen and Greg Watt, and also Bruno Ceccaroli, Jonas Sandgren and Alan Taylor.

Acknowledgements

Editing assistance was provided by several members of Task 1 and is much appreciated.

The contribution of EC information by David Anderson of the CEC is gratefully acknowledged.

The contributions of non PVPS country information (much abridged in the final version of this report) by our colleagues – IEA PVPS Task 9 (PV Services for Developing Countries), Ministry of Non-Conventional Energy Sources (India), Renewable Energy for Rural Economic Development – RERED (Sri-Lanka), Ahmad Hadri Haris, Hari Natajaran, Stanislaw Pietruszko, Chris Purcell – are also gratefully acknowledged.

Exchange rates

Table 12 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 (source: OECD Main Economic Indicators June 2006).

Table 12 – Exchange rates

Country	ISO country code	Currency and code	Exchange rate (1 USD=)
Australia	*AUS*	*Dollar (AUD)*	*1,31*
Austria	*AUT*	*Euro (EUR)*	*0,81*
Canada	*CAN*	*Dollar (CAD)*	*1,21*
Denmark	*DNK*	*Krone (DKK)*	*5,99*
France	*FRA*	*Euro (EUR)*	*0,81*
Germany	*DEU*	*Euro (EUR)*	*0,81*
Israel	*ISR*	*Dollar (USD)*	*1*
Italy	*ITA*	*Euro (EUR)*	*0,81*
Japan	*JPN*	*Yen (JPY)*	*110,1*
Korea	*KOR*	*Won (KRW)*	*1 024*
Mexico	*MEX*	*Peso (MXP)*	*10,89*
Netherlands	*NLD*	*Euro (EUR)*	*0,81*
Norway	*NOR*	*Krone (NOK)*	*6,44*
Portugal	*PRT*	*Euro (EUR)*	*0,81*
Spain	*ESP*	*Euro (EUR)*	*0,81*
Sweden	*SWE*	*Krona (SEK)*	*7,47*
Switzerland	*CHE*	*Franc (CHF)*	*1,25*
United Kingdom	*GBR*	*Sterling (GBP)*	*0,55*
United States	*USA*	*Dollar (USD)*	*1*

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 commercial product), 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 power producing system, typically available in 12,5 cm, 15 cm up to 20 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 15 % and 18 %.
Multicrystalline cells, usually manufactured from a melting and solidification process, are less expensive to produce but are marginally less efficient, with an average efficiency around 14 %.
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 % (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 with specialised products for building integrated PV systems at even larger sizes. Crystalline silicon modules consist of individual PV cells connected together and encapsulated between a transparent front, usually glass, and a backing material, usually plastic or glass. 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. Quality PV modules are typically guaranteed for up to 20 years by manufacturers and are type approved to IEC 61215 or IEC 61646 International Standards.

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** consists 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 network. The typical weighted conversion efficiency – often stated as ‘European Efficiency’ – of inverters is in the range of 94 %, with peak efficiencies up to 97 %. Inverters connected directly to the PV array incorporate a Maximum Power Point Tracker (MPPT), 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 network (where approved by network operators) but still play a minor role.

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. Other types of batteries (e.g. NiCd, NiMH) 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 depending on the operating regime and conditions 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 .

Report IEA-PVPS T1-15:2006-1 Printed in Switzerland ***www.suterdruck.ch***