TRENDS IN PHOTOVOLTAIC APPLICATIONS

Survey report of selected IEA countries between 1992 and 2008

PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

Report IEA-PVPS T1-18:2009

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Foreword

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The IEA carries out a comprehensive programme of energy cooperation 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 participants in the Programme 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.

[1] *The long-term participating countries are Australia, Austria, Canada, Denmark, France, Germany, Israel, Italy, Japan, Korea, Mexico, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States of America. The European Commission and the European Photovoltaic Industry Association are also members. Malaysia and Turkey are recent participants.*

The IEA PVPS Programme is pleased to present the 14th edition of the international survey report on Trends in Photovoltaic Applications. 2008 has been a turbulent year characterised both by dramatic industry and market expansion in a number of countries as well as first impacts from the financial crisis. Market growth was particularly strong in Korea, Spain, Italy, France and Portugal. In absolute terms, the market is dominated by Spain and Germany, followed by Italy, US, Korea and Japan. In total, more than 5.5 GW of photovoltaic power systems were installed during 2008 in IEA PVPS countries; raising the total installed capacity to 13.4 GW in those countries. The share of grid-connected, centralized applications grew to comprise 35% of the grid-connected cumulative installed capacity. On the supply side, remarkable growth can be observed along the whole value chain, in particular for silicon feedstock production and thin film technologies. The production of photovoltaic modules in IEA PVPS non-member countries has continued to increase strongly. Interest and public support continues to be high in many countries and the possible role of photovoltaics in the future power supply is getting ever more attention. The global financial crisis has reached the photovoltaic sector during its strongest growth phase, leading to partial overcapacities, expected drastic cost reductions and a more difficult environment for investment in technology development and new production facilities. In spite of these difficulties, the sustainable nature of photovoltaics and the need for a clean and secure energy supply keep this technology amongst the most prospective ones. Government support for photovoltaics has thus generally been increased. Keeping track of all the developments in and around the PV sector on the global level is a challenge which the IEA PVPS network is happy to address. I trust that this new edition of Trends in Photovoltaic Applications will 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 contact the IEA PVPS website at www.iea-pvps.org.

September 2009

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 reporting 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 14th international survey. It provides an overview of PV power systems applications, markets and production in the reporting countries and elsewhere at the end of 2008 and analyzes trends in the implementation of PV power systems between 1992 and 2008.

Energybase Passive House office building, Vienna, Austria, (Courtesy of Herta Hurnaus)

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 reporting countries. These national survey 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 some of 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 device 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. Supply chain refers to the procurement of all required inputs, conversion into finished PV products, distribution and installation of these products for final customers. The value chain looks at how increased customer value can be created across a company's business activities, which can include design, production, marketing, delivery and support functions.

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 Implementation of photovoltaic systems

1.1 Applications for photovoltaics

There are four primary applications for PV power systems:

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. Defining such systems is becoming more difficult where, for example, mini-grids in rural areas are developed by electricity utilities.

PV-Wind-Diesel Generator hybrid power system, Fethive, Mugla, Turkey (Courtesy of Girasolar Ltd.)

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.

Mt. Booboo Ergon Communications site, Queensland, Australia

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. Size is not a determining feature – while a 1 MW PV system on a roof-top may be large by PV standards, this is not the case for other forms of distributed generation.

MegaSlate System on a single family house in Amberg, Germany (Courtesy of 3S)

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. These systems are typically ground-mounted and functioning independently of any nearby development.

1.1 MWp PV Plant, Spain (Courtesy of Edisun Power)

1.2 Total photovoltaic power installed

About 5,56 GW of PV capacity were installed during 2008 (an increase of about 150 % over the previous year) which brought the total installed capacity to 13,4 GW. By far the greatest proportion (75 %) was installed in Spain and Germany alone. If Italy, the US, Korea and Japan are also included, then over 96 % of PV installations in 2008 occurred in six countries.

This report continues to be updated to reflect the best information available at the time of writing which means that totals in some tables have been amended from previous years. This enables IEA PVPS to carry out a more realistic and rigorous evaluation of trends in PV markets and policies over the last decade or so.

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 and increasing proportion of worldwide PV capacity. The annual rate of growth of cumulative installed capacity in the IEA PVPS countries was 71 %, up from

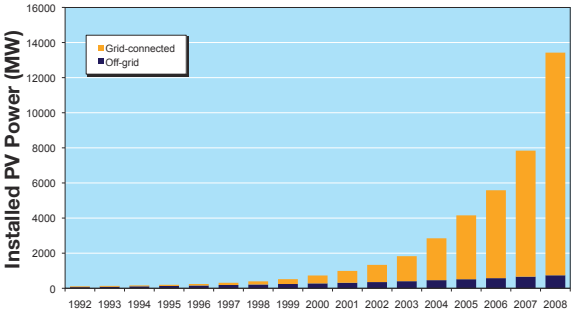

Figure 1 – Cumulative installed grid-connected and off-grid PV power in the reporting countries

Table 1 – PV power capacity in participating IEA PVPS countries as of the end of 2008

Country	Cumulative off-grid PV capacity (kW)		Cumulative grid-connected PV capacity (kW)		Cumulative installed PV power (kW)	Cumulative installed per capita (W/Capita)	PV power installed in 2008 (kW)	Grid-connected PV power installed in 2008 (kW)
	domestic	non-domestic	distributed	centralized				
AUS	32 683	40 662	29 850	1 315	104 510	5,1	22 020	15 120
AUT	3 357		27 274	1 756	32 387	4,0	4 686	4 553
CAN	10 603	16 879	5 172	65	32 719	1,0	6 944	2 326
CHE	3 800		41 540	2 560	47 900	6,4	11 700	11 500
DEU	40 000		5 300 000		5 340 000	64,7	1 504 500	1 500 000
DNK	125	315	2 825	0	3 265	0,6	190	135
ESP	31 000		3 323 000		3 354 000	77,1	2 661 000	2 659 936
FRA	16 181	6 766	140 785	16 000	179 732	2,9	104 500	104 100
GBR	480	1 110	20 920	0	22 510	0,3	4 420	4 303
ISR	2 144	260	611	14	3 029	0,4	1 210	600
ITA	5 400	7 900	295 000	150 000	458 300	7,8	338 100	337 900
JPN	1 923	88 886	2 044 080	9 300	2 144 189	16,8	225 295	224 636
KOR	983	4 960	54 852	296 722	357 517	7,3	276 324	276 324
MEX	16 087	5163	500	0	21 750	0,2	1 000	200
MYS	8 000		776	0	8 776	0,4	1 760	135
NLD	5 200		48 500	3 500	57 200	3,5	4 400	4 200
NOR	7 780	430	132	0	8 342	1,8	350	0
PRT	2 941		2 908	62 103	67 952	6,7	50 082	49 982
SWE	4 130	701	3 079	0	7 910	0,9	1 678	1 403
TUR	3750		250		4 000	0,06	750	75
USA	154 000	216 000	735 000	63 500	1 168 500	3,9	338 000	293 000
Estimated total	**310 589**	**430 010**	**8 220 204**	**4 463 685**	**13 424 488**		**5 558 909**	**5 490 428**

Notes: ISO country codes are outlined in Table 13. 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. Australian off-grid domestic total includes 2 000 kW of PV on diesel grids.

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

Country	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
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	70,3	82,5	104,5
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	25,6	27,7	32,4
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	20,5	25,8	32,7
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	29,7	36,2	47,9
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	1 034,0	1 926,0	2 759,0	3 835,5	5 340,0
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	2,9	3,1	3,3
ESP	~	~	1,0	1,0	1,0	1,0	1,0	2,0	2,0	4,0	7,0	12,0	23,0	48,0	145,0	693,0	3 354,0
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	43,9	75,2	179,7
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	14,3	18,1	22,5
ISR	~	~	~	~	~	~	~	~	~	~	~	~	0,9	1,0	1,3	1,8	3,0
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	50,0	120,2	458,3
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	1 132,0	1 421,9	1 708,5	1 918,9	2 144,2
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	13,5	35,8	81,2	357,5
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	19,7	20,8	21,8
MYS	~	~	~	~	~	~	~	~	~	~	~	~	~	~	5,5	7,0	8,8
NLD	1,3	1,6	2,0	2,4	3,3	4,0	6,5	9,2	12,8	20,5	26,3	45,7	49,2	50,7	52,2	52,8	57,2
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	7,7	8,0	8,3
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	2,7	3,0	3,4	17,9	68,0
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	4,8	6,2	7,9
TUR	~	~	~	~	~	~	0,2	0,3	0,4	0,6	0,9	1,3	1,8	2,3	2,8	3,3	4,0
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	376,0	479,0	624,0	830,5	1 168,5
Total	**105**	**130**	**158**	**192**	**237**	**305**	**386**	**510**	**716**	**975**	**1 318**	**1 810**	**2 835**	**4 188**	**5 627**	**7 866**	**13 425**

Notes: 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.

Table 3 – Annual installed photovoltaic power (MW) in selected countries – historical perspective (1995–2008)

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
AUS	2,0	3,0	3,0	3,8	2,8	3,9	4,4	5,5	6,5	6,7	8,3	9,7	12,2	22,0
AUT	0,3	0,3	0,5	0,7	0,8	1,2	1,2	4,2	6,5	4,2	3,0	1,6	2,1	4,7
CAN	0,4	0,7	0,8	1,1	1,3	1,4	1,6	1,2	1,8	2,1	2,8	3,8	5,3	6,9
CHE	0,8	0,9	1,3	1,8	1,9	1,9	2,3	1,9	1,5	2,1	4,0	2,6	6,5	11,7
DEU	5,3	10,1	14,0	12,0	15,6	44,3	80,9	83,4	153,0	603,0	892,0	833,0	1 076,5	1 504,5
ESP	~	~	~	~	~	~	2,0	3,0	5,0	11,0	25,0	97,0	548,0	2 661,0
FRA	0,5	1,5	1,7	1,5	1,5	2,2	2,6	3,3	3,9	5,2	7,0	10,9	31,3	104,5
ITA	1,7	0,2	0,7	1,0	0,8	0,5	1,0	2,0	4,0	4,7	6,8	12,5	70,2	338,1
JPN	12,2	16,2	31,7	42,1	75,2	121,6	122,6	184,0	222,8	272,4	289,9	286,6	210,4	225,3
KOR	0,1	0,3	0,4	0,5	0,5	0,5	0,8	0,7	0,6	2,5	5,0	22,3	45,4	276,3
NLD	0,4	0,9	0,7	2,5	2,7	3,6	7,7	5,8	19,6	3,6	1,7	1,5	1,6	4,4
PRT	~	0,1	0,1	0,1	0,3	0,2	0,2	0,4	0,4	0,5	0,4	~	14,5	50,1
USA	9,0	9,7	11,7	11,9	17,2	21,5	29,0	44,4	63,0	100,8	103,0	145,0	206,5	338,0

Notes: Countries that are experiencing (or have recorded in a past year) annual installed PV power of >5 MW

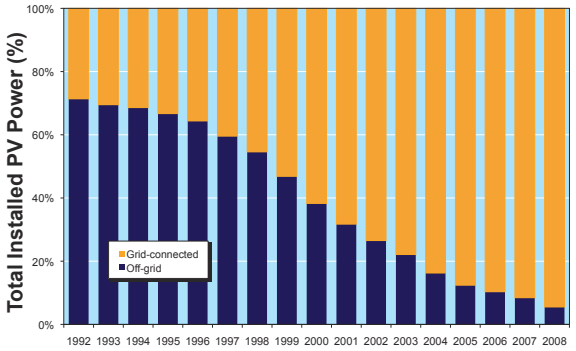

Figure 2 – Percentages of grid-connected and off-grid PV power in the reporting countries

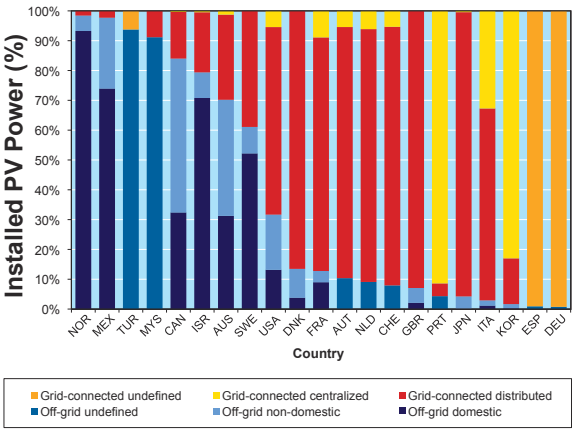

Figure 3 – Installed PV power in the reporting countries by application (%) in 2008

the 40 % recorded in 2007 (largely driven by the increasing magnitude of grid-connected PV support programmes). Four countries exceed 1 GW cumulative installed PV capacity. Spain's cumulative installed capacity increased almost five-fold. Germany's cumulative installed capacity grew at 39 % (the same as the growth rate experienced the previous year) whereas Japan's growth rate continued at around 12 %. Cumulative installed capacity in the US increased at over 40 % (up from 33 % the previous year).

Growth of the annual market was evident in a number of countries (Table 3). The Korean annual PV market increased six-fold. The Spanish annual market increased almost five-fold, as did the Italian market. The French annual PV market more than tripled as did the Portuguese market. Australia, Austria, Switzerland and the Netherlands saw their annual markets increase significantly, as did Germany and the US to a lesser degree (in relative terms). Japan's annual PV market increased slightly but has remained quite stable for a number of years. In 2008 the size of Spain's annual PV market was largest (the position previously held by Germany) by more than 1 GW, followed by Germany, and then quite a drop to the third position shared by the US and Italy.

While Germany still has the highest level of installed capacity in terms of total capacity (5 340 MW), the highest installed capacity per capita, previously Germany, is now Spain (77,1 W/capita).

Of the total capacity installed in the IEA PVPS countries during 2008, only a little more than 1 %

were installed in off-grid projects and these now make up 5,5 % of the cumulative installed PV capacity of the IEA PVPS countries. It is interesting to note that it was only a decade ago that the installed capacities of off-grid and grid-connected applications were divided almost equally. Figure 3 illustrates the proportion of various PV applications in the reporting countries. The largely unsubsidized market for vacation cottages, cost effective rural electrification, telecommunication and infrastructure applications does continue to grow worldwide, albeit less vigorously than the publicly funded grid-connected PV markets, with the cumulative installed off-grid capacity typically increasing by about 10 % to 15 % each year.

An interesting feature of last year's report was that grid-connected centralized cumulative installed capacity had increased three-fold compared to 2006, to make up 16 % of the grid-connected PV capacity. In 2008 grid-connected centralized applications grew further to comprise 35 % of the grid-connected cumulative installed capacity. This reflects the market for utility-scale PV power systems being developed in a number of countries, as outlined in the next section of this report.

1.3 PV implementation highlights from selected countries

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. Small landmark projects or programmes are as significant in some countries as policy debates and PV market expansion are in others. This section is based on the information provided in the national survey reports submitted each year by participating countries. For some countries, considerable detail is presented in their national survey report and the reader is directed to these reports on the IEA PVPS website for further details about specific markets, projects and programmes.

Australia (AUS)

More than 22 MW of PV were installed in Australia in 2008, an 80 % increase on 2007 levels. Of this, nearly 69 % were grid-connected, taking the cumulative grid-connected portion to nearly 30 %, up from 19 % in 2007. Total installed capacity in Australia reached 104,5 MW. Australian Government expenditure on PV research, development, demonstration and market incentives was 117,91 million AUD in 2008, with government market incentive programmes accounting for 88 % of the expenditure.

The largest installed capacity of PV in Australia is for off-grid industrial and agricultural applications. Significant markets also exist for off-grid residential and commercial power supplies and increasingly for fuel saving and peak load reduction on community diesel grid systems.

The market for PV installations connected to the main electricity grids continues to increase and represented the largest market for PV in 2008. The majority of installations took advantage of a government grant programme (the Solar Homes and Communities Plan) which contributed up to 80 % or more of up-front capital costs. The main applications are rooftop systems for private residences, schools and community buildings. Commercial and light industry sector interest is also growing, with support available to selected projects through the Solar Cities Program. All grid-connected PV systems can create Renewable Energy Certificates for the Renewable Energy Target.

Australian Government support programmes impacted significantly on the 2008 PV market, contributing funding towards 74 % of PV capacity installed over the year. The Solar Homes and Communities Plan (SCHP) provided rebates up to 8 000 AUD for 1 kW of PV installed on residential buildings and up to 50 % of the cost of PV systems up to 2 kW installed on community buildings. A household income means test applied, and caused significant public debate and high exposure for the programme. This programme had the most impact on the PV market in Australia during 2008, with 12,2 MW of PV installed and grants of 68,4 million AUD provided. A total of 27 MW of PV had been installed under this programme to end 2008. From late 2009, the rebate is expected to be replaced by extra Renewable Energy Certificates from the Renewable Energy Target.

Several State governments and the Alice Springs Solar City have introduced feed-in tariffs for small PV systems. The rates, system sizes and length of time vary but all State schemes to date are net export. The Alice Springs scheme is gross, as is the planned ACT scheme, to be introduced in 2009.

In 2008 the Solar Cities programme saw two new cities announced, Moreland and Perth, expanding the programme to seven Solar Cities. Four Solar Cities were operational in 2008: Adelaide, Blacktown, Alice Springs and Townsville. The four operational cities installed a total of 550,5 kW of household PV in both private and public houses and 166 kW of PV on commercial and iconic buildings. All Solar Cities include electricity utilities in the consortia. Trials of new technologies, new tariffs and new deployment methods are being held, with accompanying education and awareness raising.

The 480 million AUD National Solar Schools Programme (NSSP) commenced on 1 July 2008 and finishes on 30 June 2015. NSSP offers primary and secondary schools grants of up to 50 000 AUD to install solar and other renewable power systems, solar hot water systems, rainwater tanks and a range of

energy efficiency measures including insulation, energy efficient lighting and ceiling fans.

The Renewable Remote Power Generation Programme (RRPGP) provided rebates of up to 50 % of the capital cost of renewable energy and related components used for diesel displacement in stand-alone power systems. In 2008 a total of 2 472 kW of PV were installed in remote residences and 1 080 kW in non-residential systems. A total of 36,7 million AUD was provided in rebates. In total 11,92 MW of PV have been installed under RRPGP to end 2008. 980 000 AUD was provided from the Industry Support component of the RRPGP for 64,9 kW of PV in the new Alice Springs Desert Knowledge Australia Solar Centre where a range of different systems and configurations are being monitored and tested.
Bushlight installs renewable energy systems in remote Indigenous communities (known as homelands) throughout central and northern Australia. Each system installation is preceded by, and carried out in conjunction with, a comprehensive programme of community engagement, education and training. The project is partially funded by RRPGP. In 2008, Bushlight installed 17 new renewable energy systems, with a combined total of 171 kW of PV. Bushlight also coordinates a maintenance program that serviced more than 150 renewable energy systems by the end of 2008.

A large portion of the 2008 PV market was served by imported PV products and in addition BP Solar announced the closure of its Sydney manufacturing plant in 2009. However, the high capital rebates, and the subsequent high PV uptake levels, saw a number of local market innovations in 2008. One was the emergence of bulk purchase and install schemes, whereby households signed up for a low cost system, on the basis of sufficient local interest (typically 50 homes) being shown. Bulk purchase of lower-cost Chinese modules, combined with streamlined installations in a local area allowed prices to fall considerably, for the first time in a number of years. The rapid growth of the grid-connect market was also accompanied by an increase in accreditation of electricians and other installers and the introduction of many new players in the market.

Austria (AUT)
After a two year slump, the Austrian PV market more than doubled in 2008 compared to 2007. During 2008, off-grid and grid-connected PV systems with a total PV power of 4,7 MW were installed. Despite this positive development, the domestic PV market is still far from its historical peak of 6,5 MW achieved in 2003. Over a decade average market growth of 22 % per year for all PV installations and 26 % for grid-connected installations has been experienced in Austria.

The cumulative installed PV capacity in Austria reached 32,4 MW at the end of 2008. Grid-connected applications increasingly dominate the market for PV, accounting for more than 89 % of the cumulative installed capacity by the end of 2008. As in previous years, the off-grid sector plays a minor role in the Austrian PV market, with only 0,13 MW installed during 2008. An estimated cumulative capacity of 3,4 MW of off-grid systems for domestic and non-domestic applications has been installed in Austria by end 2008.

PV implementation programmes in Austria have been mainly characterized by discontinuity. The Austrian framework for renewable energy support had been based on diverse local and regional incentives and in 2003 the implementation of the federal Green Electricity Act (Ökostromgesetz) marked an important turning point. The preferential feed-in tariffs for electricity from renewable sources together with a purchase obligation for green electricity created a very attractive environment for investment in PV. However the availability of the PV feed-in tariffs was capped to a national limit of 15 MW installed PV – which was reached very quickly. After a period of three years with no federal support for PV, Austria's parliament passed a revision of the green electricity act which has been effective since late 2006. The key conditions of this framework during 2008 as they relate to PV include: specific shares of the support for the various energy sources are defined, with only 10 % reserved for PV, liquid biomass, co-firing power plants and some other applications; the total funds for the feed-in tariffs for new installations are limited on a yearly basis; and, for PV alone, the provinces are requested to double the federal subsidy, which makes the support system even more complex.

PV feed-in tariffs for new installations are defined on a yearly basis in a separate Feed-in Decree. According to the 2008 Feed-in Decree tariffs ranged from 0,4599 EUR/kWh for installations < 5kW down to 0,2999 EUR/kWh for >10kW systems and remained on the same level as in 2007. For installations supported under the feed-in tariff scheme 100 % of the specific tariff is paid for the first 10 years. Afterwards, the tariff is cut to 75 % in year 11 and finally 50 % in year 12. After this period, only the gross sale price for electricity is paid. The feed-in tariff system is financed by all consumers of electricity via supplements on the electricity price and an obligatory purchase price for green electricity which has to be paid by electricity dealers. The feed-in tariffs paid for PV in 2008 amounted to approximately 10,4 million EUR.

Besides the federal feed-in tariff scheme, a new short-term initiative was launched through the newly-founded national Fund for Climate and Energy. The initiative, which provides rebates for newly installed private PV systems up to 5 kW, was launched in August 2008 with a total budget of about 10 million EUR.

To further complicate the situation, four of the nine provinces are still running regional rebate programmes, aimed at overcoming the limitations of federal incentives. In most cases the support is

subject to limited budgets and is linked to further requirements. Generally, the regional support is only granted when the installation is not supported by the federal feed-in tariff scheme.

A major trend regarding Austrian PV projects in recent years – optimal architectural integration of BIPV in newly constructed and refurbished buildings – continued during 2008. ENERGYbase, a showcase project of a new generation of office properties, has been realized in 2008 in the city of Vienna and incorporates energy efficiency, the application of renewable energy sources and a high level of comfort for occupants. An approximately 400 m² PV system (about 50 kW) located on the south façade supplies roughly 42 000 kWh of solar electricity. Solar thermal collectors supply the solar cooling system with energy in the summertime, whereas the thermal energy is used to support the heating system during the winter season. Passive use of solar energy is made possible by the special shape of the south façade, which only allows direct solar radiation into the building during the winter. Plants are integrated into the office complex in a green buffer zone to help humidify the air, functioning as a closed moisture generating system.

Canada (CAN)

Canada's total installed PV capacity increased by 27 % to 32,72 MW in 2008 compared to 2007. Total PV sales in Canada (domestic and export) in 2008 were 28,26 MW, a 125 % increase over the previous year. The growth of the PV market in Canada has been averaging 26 % annually since 1993, and about 36 % annually since 2000.

Eighty four percent of installed PV systems in Canada consist of off-grid applications comprising a PV array as the sole generator or as a hybrid system combined with a small wind turbine or diesel generator. These systems are usually sited remotely with or without battery storage, and are increasingly being applied closer to the electricity grid as relative costs change and design professionals and the public become more aware of opportunities.
The off-grid residential and non-residential markets represented 66 % of the total PV market in Canada in 2008.

Sales in the grid-connected sector accounted for 34 % of the PV market in Canada in 2008. This is a growing application sector spurred by the Province of Ontario's new feed-in tariff launched in 2006 under the Renewable Energy Standard Offer Programme (RESOP). In 2008 the Province of Ontario's RESOP exceeded all expectations – achieving in excess of 1 000 MW of contracted projects – surpassing the ten year target for renewable energy in the first year. Because of its popularity, a comprehensive review of the programme was undertaken in 2008 in order to facilitate changes required to ensure its continued success.

The ecoENERGY for Renewable Power (ecoENERGY RP) programme (announced in early 2007) was revised in 2008 to address issues raised during the first year of operation. The programme was designed to encourage the production of 14,3 TWh of clean electricity from low impact renewable energy sources, such as solar photovoltaic, wind, hydro, and biomass and ocean energy. In 2008 the programme registered 227 projects with a total capacity of about 11 250 MW.

Technology Early Action Measures (TEAM), a federal interdepartmental technology investment programme that has supported late-stage development and first demonstrations of greenhouse gas reducing technologies since its inception in 1998, began to wind-down its activities in 2008 as its mandate came to an end. TEAM was instrumental in funding PV technology demonstrations in Canada with total investments of 12 million CAD in eight PV early market / entry ready projects – the most recent ones being the development and demonstration of combined solar PV and thermal power generation technologies in net-zero energy homes and low energy commercial and institutional buildings in collaboration with the Canadian Solar Buildings Research Network, and the development and demonstration of solar powered stand-alone next generation LED lighting.

The Solar Buildings Research Network is generating opportunities for demonstrations of innovative PV projects in Canada and is expanding the knowledge base of the benefits and added value of PV technology in the buildings of the future. The collaborative R&D focus is providing in-depth analyses to Canadian stakeholders on the optimization of low and net-zero energy homes for Canadian climatic conditions and is helping to support innovation in the residential construction industry in order to accelerate the adoption of low and net-zero energy solar homes.

Denmark (DNK)

By the end of year 2008 Denmark (including Greenland) had about 3,3 MW of PV installed in total, an increase of almost 200 kW compared to 2007. Grid-connected distributed systems make up the majority (90 %) of PV systems in Denmark. The national electricity grid covers practically the whole country and leaves little room for stand-alone applications. In Greenland stand-alone PV plays a major role as the power source for remote signalling and for the telecommunication network extending more than 2 000 km on the western coast line.

During 2008 there was slow progress in the main market sector of grid-connected distributed systems. Only the regional distribution utility EnergiMidt provided incentives in their own concessionary area in the form of an investment subsidy of up to 40 % of the investment cost of a grid-connected PV system.

However grid-connected PV applications are seen as the largest potential PV market in Denmark, in particular building integrated applications on single family houses, apartment buildings, commercial and office buildings. The public interest for building integrated PV is increasing, and most efforts are focused on developing and demonstrating PV in the context of existing buildings.

In early 2008 the government confirmed its commitment to support renewables and a new energy plan, 'A Visionary Energy Policy', extending out to 2025 was agreed. Public funding for R&D into energy is expected to be doubled to one billion DKK by 2010. Over a three to five year period more than 150 million DKK will be allocated to renewables R&D; however it is still too early to say to what extent PV will benefit from these initiatives. PV has been specifically mentioned for the first time in the government's energy plan. The government allocated a further 25 million DKK per year for an initial four year period in support of demonstration of emerging renewables such as PV and wave power; in early 2009 the PV-Skive project received a grant of 21 million DKK to implement at least 1 MW of BIPV on the buildings of the municipality of Skive.

Denmark's national building code (revised to align with the EU directive on energy consumption in buildings) also specifically mentions PV and allocates PV electricity a factor of 2,5 in the calculation of the 'energy foot-print' of a building. However due to inertia in the construction sector it is too early to see any real impact on PV deployment, although ongoing political discussions indicate a further tightening of the building codes.

France (FRA)

During 2008, 104,5 MW of PV were installed in France (mainland France, Corsica and the four French overseas departments Guadeloupe, Guyane, Martinique and Réunion), a more than threefold increase compared to the 31,3 MW installed during 2007. The growth is mainly due to the national fiscal measures (new feed-in tariff and tax credit) launched from 2006. Grid-connected distributed systems and grid-connected centralized systems accounted for over 84 % and 15 % respectively of the annual market. Cumulative capacity at the end of 2008 was 179,7 MW of which 87 % are grid-connected.

In 2008 in mainland France the feed-in tariff for photovoltaic-generated electricity was 0,31193 EUR per kWh (increasing to 0,32823 EUR per kWh in 2009) with a building integrated PV (BIPV) bonus of 0,25594 EUR per kWh (increasing to 0,27353 EUR per kWh in 2009). The French Government decided to place an emphasis on BIPV and reflected this in the feed-in tariff structure. Higher feed-in tariffs are available in Corsica and the French overseas departments. Feed-in tariff contracts are signed for a 20 year period and are to be revised every year on the basis of a specific inflation index.

Other measures complemented the feed-in tariff support programme, namely an income tax credit applying to 50 % of PV module and other equipment costs and capped at 8 000 EUR per income tax paying person (16 000 EUR for a couple), and the ongoing ADEME – FACE support for off-grid systems.

Regional support is also available for PV deployment. This can vary widely according to the target application (for example residential, primary residence, BIPV etc), the nature of the programme (for example individual requests or calls for projects), criteria applied (for example total cost, labour cost, part costs, estimated annual energy production), maximum support (total or per watt, for example) and amounts allocated to different facets of a system (for example on the investment cost or the labour cost or the total cost, per W or per kWh).

The combination of these incentives has had many positive effects on the dynamics of the French PV market, including significant growth of PV applications for individual homeowners, diversification of the types of PV applications, evolution of the structure of the PV industry supply chain, progression of technological innovations from R&D to new products, and the creation of skilled jobs.

Germany (DEU)

Market support measures promoting grid-connected roof-top systems and large PV power plants by means of a PV electricity feed-in tariff continued to significantly accelerate the installation of grid-connected PV systems in Germany during 2008. The BSW published a figure of 1 500 MW of new grid-connected PV capacity for the year, bringing the German cumulative capacity to over 5,3 GW. In addition to the market for grid-connected systems, there has been steady growth in the market for stand-alone systems. Indications are that in 2008 around 5 MW of off-grid PV were installed mainly for industrial applications such as the automotive sector, traffic signals etc.

By end 2008, more than 500 large-scale PV plants, each with an installed capacity greater than 200 kW, are in operation in Germany. The installed capacity of these large PV plants amounts to about 700 MW and 120 new large plants were brought into service during 2008.

The reported PV capacity installed in Germany in recent years remains a topic of discussion, with the high number of installations making it difficult to track each system. However, since the beginning of 2009, owners of new PV systems are now legally obliged to register their systems with the German Federal Network Agency. Only registered systems will receive the favourable feed-in tariff.

The German Government has developed an integrated energy and climate programme that comprises a number of measures dealing with energy efficiency and renewable energies in the electricity and

heat sectors, and also transportation. Initially, for the electricity sector, a national target for renewable energies of 12,5 % by 2010 and 20 % by 2020 was set. By 2008 the renewables share in the electricity sector reached almost 15 %, exceeding the 2010 target set some years ago. In mid 2008 the German Parliament decided to set a new target of 30 % by 2020.

The Renewable Energy Sources Act (EEG) governs the favourable payments for renewable electricity. For PV rooftop systems smaller than 30 kW payments under the feed-in tariff have evolved as follows (in EUR/kWh): 2003 – 0,46; 2004 – 0,574; 2005 – 0,545; 2006 – 0,518; 2007 – 0,492; 2008 – 0,4675; and 2009 – 0,4301. In order to stimulate a stronger price reduction, the degression rate of tariffs for new PV systems was raised from 5 % to 8 % in 2009 and 2010 (for systems smaller 100 kW). Moreover, the degression rate will now be adapted to market conditions. If the market deviates from a predefined corridor, the degression rate will be increased or decreased by 1 % for the following year. For 2009 the corridor was set between 1 000 MW and 1 500 MW. The rates are guaranteed for an operational period of 20 years. The bonus for façade integrated systems was eliminated. For small systems (< 30 kW) installed in 2009 it is also possible obtain a reimbursement of 0,25 EUR/kWh for PV power consumed by the PV owner or his near neighbours.

In addition to the EEG, PV in Germany receives support from other sources: local fiscal authorities provide tax credits for PV investments (Investitionszulage); the bank KfW provides loans for private PV investments (Erneuerbare Energien Standard), for community PV investments (Kommunal investieren) and for community infrastructure investments (KfW- Kommunalkredit); and various federal states provide grants or loans.

There is a broad awareness and acceptance of renewable energy and PV by the German public. Consequently a constant demand exists for PV products. The PV industry is regarded as an important component of the national technology sector and attracts considerable attention in the community. Due to the relatively mature PV market in Germany technically-orientated demonstration and large field test activities are no longer of much interest. Industry focuses their activities on process optimization to reduce production costs and to increase the quality of their products. Recycling is also attracting more attention.

Israel (ISR)

During 2008 about 1 MW of PV were installed in Israel, bringing the cumulative installed capacity to over 2,2 MW. In contrast to previous years the majority of systems installed were grid-connected. Off-grid systems still dominate the cumulative installed capacity with about 72 % of the total.

28 kW PV System on a secondary school, Gap, France (CG des Hautes Alpes)

Mid 2008 saw the implementation of Israel's new policy to allow grid-connection of private PV installations, with a subsidy specifically calculated to encourage small projects (up to 50 kW). The public response to the new policy was good, though actual sales were slower to develop. Most PV installations in 2008 were in the rural sector. Of the 600 kW grid-connected PV installed in 2008, most systems were on farm roof-tops.

Implementation of PV grid-connected systems is divided by installation size, defined as small (up to 50 kW), medium (up to 5 MW) and large (over 5 MW). During 2008, only small systems were installed. An attractive feed-in tariff for small systems was set originally at 2,04 NIS/kWh (four times the retail electricity price). For private household systems (defined as under 4 kW) the system owner is exempt from income tax, providing an added incentive. The tariff has already fluctuated to a lower level, as it is based on a complicated formula taking into account international monetary fluctuations.

As with any new endeavor involving multiple parties and areas of responsibility, a number of issues were uncovered as the programme progressed from proposal to implementation. Most issues – such as some municipalities' requirements for building permits – were resolved during 2008. Others have now been resolved in 2009, such as the willingness of the Israel Electric Corporation (IEC) to transfer feed-in tariff refunds to third parties who had provided credit for loans. Some issues remain to be resolved, such as property taxes on building improvements (including PV installations).

The country's sole electricity company, IEC, has explicitly stated that it is in favor of the new grid-connected PV programme and is trying to encourage it, for example through information mailed to customers.

Italy (ITA)

In 2008 over 338 MW of PV power were installed in Italy, almost five times the size of the market in 2007. Cumulative installed PV power reached 458 MW. The grid-connected distributed and grid-connected centralized PV power systems markets are growing rapidly and now account for 64 % and 33 % respectively of the total installed capacity. Off-grid non-domestic PV applications continue to increase slowly and constantly.

The main national market stimulation initiative in operation during 2008 was the Conto Energia Programme. The first phase, called Primo Conto Energia, resulted in the installation of over 5 000 PV plants (corresponding to about 120 MW) by the end of 2008 and is expected to be completed by mid 2009. The second phase, called Nuovo Conto Energia, has been defined through a governmental decree issued early in 2007 and has resulted in the installation of about 27 000 PV plants, corresponding to about 300 MW.

The rapid market growth continues to be driven by the changes to the feed-in tariff decree which were adopted in early 2007. Whereas the support amounted to about 20 million EUR during 2007, this figure increased to about 80 million EUR during 2008. The feed-in tariff value depends on the degree of PV integration in the building, up to 0,49 EUR/kWh, but reduced for large plants (for example, a large free-standing plant can earn 0,36 EUR/kWh). The tariffs remain valid for 20 years at a constant rate and will be reduced by 2 % each calendar year after 2008. Additional amounts are earned for the sale of electricity to the grid or for own consumption of the electricity. Further bonuses are also available.

The limit of 1 200 MW PV supported by Conto Energia is expected to be reached by 2010. The programme has provided stability and enabled the expansion of the PV market in Italy. Bureaucratic problems relating to the incentive mechanism have been overcome and those concerning plant construction and grid connection appear to have been resolved.

An interesting initiative of the public stakeholder AEEG (National Authority for Electric Energy and Gas) regards the simplification of the procedure for the connection of plants to the electricity grid. It is expected that this scheme will considerably reduce the time taken to develop PV plants.

Japan (JPN)

During 2008 a total of about 225 MW of PV were installed in Japan, a slight increase on the 210 MW installed the previous year. The primary factor leading to the flat growth was the termination of the budget for the Residential PV System Dissemination Programme. Most of these installations (around 221 MW) continued to be grid-connected distributed PV systems, with a further almost 4 MW comprising grid-connected centralized plants. In 2008 cumulative installed PV capacity in Japan exceeded 2,1 GW.

2008 represented an important milestone in Japan's efforts to develop the institutional frameworks, policy support and budget enhancements necessary to accelerate the widespread installation of PV from around 2009 onwards. Former Japanese Prime Minister Fukuda announced that Japan would broaden and expand the use of PV, as enunciated in the so-called Fukuda Vision. Key matters arising, as they relate to PV deployment, include: Cabinet approval of an Action Plan for Achieving a Low-Carbon Society that sets goals for PV installation amounting to 14 GW by 2020 and 53 GW by 2030; Ministry of Economy, Trade and Industry (METI) decision to promote the use of PV systems throughout Japan, through a return to the subsidy for residential PV systems and new laws for the purchase surplus energy; the joint announcement by METI, Ministry of Education, Culture, Sports, Science and Technology (MEXT), Ministry of Land, Infrastructure and Transport (MLIT) and the Ministry of the Environment (MoE) of the Action Plan for Dissemination of PV Power Generation; and the launch by a number of local governments of projects to promote installation of PV systems (for example, Tokyo Metropolitan Government will promote the installation of about 1 000 MW of PV).

From the relevant 2008 national budgets of METI and MoE (amounting to 21 570 million JPY) 7 700 million JPY were allocated for R&D for all new and renewable energies, and 3 700 million JPY were specifically allocated by METI for R&D related to PV power generation. 12 170 million JPY were allocated for demonstration / field test programmes. The budget for market revitalization amounted to 1 700 million JPY. The major national programmes relating to PV include: Technological Research and Development on New and Renewable Energy; Field

Minato Mirai 21 moving walkway PV System 79 kW, Yokohama City, Japan (Amorphous Silicon PV modules, Submodule by Fuji Electric, Module by Sanko Metal Industrial).

Test Project on New Energy Technology; Verification of Grid Stabilization with Large-scale PV Power Generation System; Project for Supporting New Energy Operators; Project for Promoting the Local Introduction of New Energy; Project for Establishing New Energy Vision at Local Level; Project for Promotion of Non-profit Activities on New Energy and Energy Conservation; Project for Developing Technology to Prevent Global Warming; Project for Promoting Eco-friendly Houses; Project for Accelerating Introduction of Renewable Energy; Project for Promoting the Creation of Low Carbon Society Model Area; and Project for Promoting the Development of Environment Technology Using Nanotechnology. Besides METI and MoE, MLIT and MEXT as well as other ministries and agencies are promoting the introduction of PV systems. Local governments and municipalities have also implemented their own subsidy programmes for residential PV systems.

Electricity utilities continue to support the deployment of PV systems through the Green Power Fund and net billing is voluntarily offered for surplus electricity generated by PV systems. In addition, utilities have decided to construct 30 PV power plants with a total capacity of 140 MW throughout Japan, aiming to accomplish these goals by FY2020. PV electricity can meet obligations under the Renewables Portfolio Standard (RPS) Law; METI has revised the RPS Law, setting a target amount of new and renewable energy in 2014 of 16 billion kWh, and has also developed measures to double count electricity generated by PV systems.

Korea (KOR)

The cumulative installed power of PV systems in Korea increased to 357,5 MW by the end of 2008. The annual installed PV power during 2008 reached 276 MW, six times the size of the market in 2007, with the majority being installed due to the favourable feed-in-tariff scheme. Grid-connected centralized systems accounted for 83 % of the total cumulative installed PV power. Fifty percent of these systems are larger than 1 MW and 90 % of them are larger than 100 kW. The largest system is the 24 MW PV plant installed in Shinan County by the Dongyang Construction Company. Grid-connected distributed systems amounted to 15 % of the total cumulative installed PV power and these were mainly installed under the feed-in-tariff scheme and the 100 000 roof-top programme. The share of off-grid non-domestic and domestic PV systems has continued to decrease to about 2 % of total cumulative installed PV power.

PV remains a priority area for Korean Government support. In 2008 the total budget for PV was 272 369 million KRW, more than twice the amount of the previous year. The budget for R&D in 2008 tripled to 58 159 million KRW, and the budget for market incentives was doubled to 214 210 million KRW. The Ministry of Knowledge Economy (MKE) publicly released the Third Basic Plan on New and Renewable Energy Sources R,D&D in 2008, including the plans for the construction of one million green homes and 200 green villages by 2020. Incorporating the previous 100 000 rooftop PV programme, and utilizing PV as well as solar thermal, fuel cells, wind, bio-energy and geothermal energy, single-family houses and multi-family houses including apartments can benefit from the support available. The government provides 60 % of the initial PV system cost for single-family and private multi-family houses, and 100 % of the cost for public multi-family rental houses.

From October 2008, the feed-in tariff rate for PV was reduced (from 711,25 KRW/kWh to 646,96 KRW/kWh for systems less than 30 kW in size) but the cap for the scheme was increased from 100 MW to 500 MW. Lower rates apply for larger systems and the beneficiaries can choose contract periods of 15 years or 20 years. By end 2008, a total of 300 MW of PV were installed under this scheme, and the annual spending in 2008 was 113 144 million KRW. It is planned that a Renewable Portfolio Standard will replace the existing feed-in tariff scheme from the year 2012, and grid parity is anticipated around 2020.

Under the Deployment Aid Programme the government provides 60 % of the installation cost for conventional PV systems and 80 % for special purpose demonstration systems. From 2008, the General Deployment and Regional Deployment Programmes were merged within this programme. During 2008, 162 PV systems totaling 8,3 MW were installed in schools, public facilities, welfare facilities and universities.

New public buildings larger than 3 000 square meters must spend 5 % of the total construction budget installing renewable energy under the Public Building Obligation Programme, changing to meeting 5 % of the total energy load from the end of 2008. This is anticipated to provide a large market for PV as the government pursues both the New Administration-Oriented City Plan and the Plan for Public Enterprise Relocation.

Malaysia (MYS)

By the end of 2008 Malaysia had a total installed PV capacity of about 8,8 MW, of which 776 kW (54 installations) were grid-connected. The largest installation is the 362 kW system at the Enterprise Four Building at Technology Park Malaysia. During 2008 there were over 135 kW of grid-connected systems installed and an estimated 1 625 kW of off-grid systems. Of the 24 new grid-connected installations in 2008, two were for office buildings and 22 for residences. The two commercial buildings made up 40 % of the total installed grid-connected PV capacity in 2008.

4.8 kWp PV System, Shah Alam, Malaysia

The main market driver for grid-connected PV systems is the financial incentive programme provided by SURIA 1000, based on a bidding process that spreads over six calls with the final call ending 1st December 2009. Other incentive programmes are the Demonstration Category (providing 25 % capital incentive for a total of 200 kW) and Showcase (providing 100 % capital incentive for a total of 100 kW). Both programmes have been fully awarded. By the end of 2008, SURIA 1000 had completed four of the six calls, with the following results: a total of 342 kW of PV installed (compared with the target of 300 kW); 13 % drop in the price of grid-connected PV systems; and, by the fourth call, bidders' willingness to pay reaching 57,8% of total system price, up from 46,7% during the first call.

During August 2008 the Government of Malaysia announced an exemption on import duty and sales tax for PV systems – this should decrease the price of PV systems by 5 % to 10 %. Companies continued to enjoy the double tax allowances (investment tax and capital allowances) announced in the previous year's budget.

The cumulative installed capacity of grid-connected PV systems in Malaysia is expected to reach 980 kW to 1 MW by the end of 2009. The cumulative capacity of off-grid PV systems is expected to reach about 10 MW by this time. Malaysia plans to introduce a feed-in tariff scheme in the 10th Malaysian Plan (2011 – 2015) for renewable energy market acceleration. By 2011, Malaysia aims to achieve 217 MW of renewable energy in the electricity supply system, with PV contributing 7 MW; by 2015 the corresponding figures are 975 MW and 55 MW; and by 2030 renewable energy is expected to represent 13% (3 484 MW) of total system capacity.

Mexico (MEX)

During 2008 about 1 MW of PV were installed in Mexico, bringing the cumulative installed capacity to around 21,7 MW. It is estimated that the share of grid-connected PV systems installed exceeded 20 % of the annual market in 2008.

The private sector became more active in the implementation of PV projects. For example, Wal-Mart Mexico began to plan for the installation of PV systems in their stores across the country. The largest PV roof-mounted system in Mexico to date was installed on the roof of a supermarket in the city of Aguascalientes at the end of 2008. The system was designed to provide around 20% of the electricity needs of the building.

During 2008 studies were carried out to estimate the penetration limits for PV electricity in an electricity distribution zone of northern Mexico. Studies on the provision of PV energy based services for isolated communities were also undertaken. During the year the Congress released The Law of Use of Renewable Energy and Financing of the Energy Transition. This is a first step in the promotion and stimulation of renewable energy in Mexico.

The Netherlands (NLD)

During 2008 about 4,4 MW of PV (about 95 % grid-connected) were installed in the Netherlands, bringing the cumulative installed capacity to 57,2 MW. This represents about a two to three times expansion of the annual markets of the past three years, after a collapse post 2003.

The change from the previous years has been due to the commencement of a feed-in tariff in 2008 for small scale PV installations. The initial tariff was for an additional 0,33 EUR/kWh for PV electricity delivered to the national electricity grid for a period of 15 years. This tariff will be adjusted each year according to changing electricity market prices. The total additional PV capacity to be installed in the period 2008 to 2011 is expected to be 78 MW. Larger PV installations (up to 100 kW) will be able to be supported from 2009. Recipients of the feed-in tariff can choose to install their PV system over a limited number of years and consequently part of the budget granted in a given year may not be spent in that year. The budget granted in 2008 corresponds to an installed PV capacity of 18 MW.

In mid 2008 a new impetus to an energy transition was given by the Innovation Agenda for Energy. About 9 million EUR were allocated to PV demonstration projects, to be developed in 2009, concerned with the integration of PV in the built environment. Some commercial banks have begun to expand their mortgage facilities with loans for PV installations, however reliable and transparent performance information about different PV systems is needed to support these services.

Norway (NOR)

About 350 kW of PV were installed in Norway during 2008, mostly in off-grid systems, with the annual market remaining at the same level as the previous three years. Off-grid domestic applications account for 93 % of Norway's cumulative installed PV capacity of about 8 MW.

After 1992 the market for off-grid domestic applications slowed due to saturation. More recently this market segment has seen purchases of additional PV capacity to serve home appliances such as televisions, freezers, refrigerators etc. Replacement of older systems has also created market growth. The slow-down in the off-grid domestic market was partly compensated for by demand from professional applications, mainly PV powered coastal lighthouses and lanterns. Even north of 70 degrees latitude lighthouses are powered by PV systems incorporating a NiCd battery-bank that ensures power supply during the dark winter months. A typical storage capacity is 120 days without power from the PV system. About 2 700 installations serving lighthouses and coastal lanterns have been installed. Some industrial applications involving small installations, such as weather stations, stations for collecting hydraulic data and so on, are growing.

In contrast to many countries in Europe, Norway does not have any incentive schemes supporting the installation of PV systems. Consequently, there are very few grid-connected systems. There are some installations however, such as the 17,5 kW PV system installed at the Oslo Innovation Centre and the 35 kW system on the southern façade of the new Oslo opera house. Some home builders have installed grid-connected PV systems on private houses. There have not been any new large PV installations in Norway during 2008.

The highlight of the Norwegian PV story remains the remarkable industrial global development of the Renewable Energy Corporation (REC). In addition, new facilities owned by Elkem Solar and NorSun have commenced production during 2008.

Portugal (PRT)

2008 saw yet another dramatic increase in the amount of PV installed during the year and also in Portugal's cumulative installed PV capacity. About 50 MW of grid-connected applications were realized and cumulative installed capacity jumped from close to 18 MW to 68 MW. The annual market has grown by several hundred percent over each of the previous two years. Grid-connected centralized systems account for 91 % of the cumulative installed capacity in Portugal.

The most significant policy initiative driving this market growth is the continuation of the independent power producer (IPP) law. The IPP law sets feed-in tariffs according to renewable technology and was revised in 2007. Under the independent power producer law one of the world's largest centralized PV plants started operation in 2008 – the Moura power plant, with an installed capacity of 45,6 MW. The Moura plant is owned and operated by Acciona Energy, comprises 262 080 PV modules, 2 520 Buskil azimuthal trackers, occupies an area of 250 hectares and has an estimated annual output of 93 GWh (giving a final yield of slightly over 2 000 kWh/kW).

The new micro-generation framework, known as Renewables on Demand became fully operational in April 2008 and was the major new PV policy initiative for the year. This framework is specifically designed for electricity consumers and consists of two regimes: the general regime, applicable to any type of micro-generation (or cogeneration) source, with a maximum interconnection power of 5,75 kW and the special regime that applies exclusively to renewable sources, with a maximum interconnection power of 3,68 kW. Both regimes are supported with feed-in tariffs, the former defined annually by the national Energy Regulator. Under the second regime, a reference feed-in tariff of 0,65 EUR/kWh applies, reduced to 95 % of its previous value for each additional 10 MW of capacity installed. The new framework requires all the electricity produced to be sold to the electricity supplier. An interesting requirement is that installation of a solar water heating system is mandatory. During 2008 a total of 5 768 registrations were received, corresponding to a capacity of approximately 20 MW, but only about half paid the required registration fee and continued with the licensing process. Of these, 615 systems (2,23 MW) were installed in 2008 and a further 2 000 systems (6,6 MW) were being constructed. More than 96 % are PV systems.

Other measures stimulating the PV market include a reduced VAT rate on renewable equipment, custom duties exemption and income tax reductions on solar equipment, and building regulations requiring all new buildings to install solar thermal systems or a specified amount of energy produced from other renewable technologies such as PV.

Spain (ESP)

Annual installed PV power in Spain reached 2 661 MW in 2008 – almost five times the size of the market in 2007 which, in turn, had represented a fivefold increase in the size of the market the previous year. In 2008 Spain overtook Germany to lead annual installed capacity by more than one gigawatt. The momentum already experienced during 2007 increased dramatically as a result of the feed-in tariff scheme. Currently the distribution of PV installations in Spain is about 99 % grid-connected systems and 1 % off-grid systems, with the total number of PV systems being around the 50 000 mark.

A feature of the Spanish PV market is the amount of large-scale installations. There are a few plants with

installed capacities ranging from 30 MW up to 60 MW. Plants with an installed capacity greater than 5 MW account for 44 % of installations. The corresponding percentages for plants between 2 MW and 5 MW capacity and less than 2 MW capacity are 20 % and 36 % respectively. Ground-mounted PV plants make up 98 % of the installations. The interest in and market implementation of high concentration PV systems (including the 7,8 MW Villafranca plant installed in 2008) is another feature of the Spanish market. Similar to other countries, projects including an innovative element for building integrated PV are also attracting some interest.

Following mounting concern about the growth rates experienced in the Spanish PV market in recent years, the relative lack of PV installations in the residential sector and the ability of locally produced PV products to compete with cheap imports (particularly from China) dramatic changes to the support scheme have been introduced (Royal Decree 1578/2008 published September 2008). In particular, the feed-in tariff is subject to a new classification of eligible PV plants (essentially roof-top systems, up to 2 MW capacity, and ground-based systems, up to 10 MW capacity); a number of administrative checks and balances have been introduced (at both the national government and autonomous community levels); quotas have been introduced for PV power installed each year (in practical terms this amounts to 500 MW in 2009 – 267 MW for roof-top systems and 233 MW for ground-mounted systems); and the tariffs themselves have been reduced (to 0,32 EUR/kWh and 0,34 EUR/kWh) and are now subject to degression provisions. The changes have been so dramatic that it is anticipated that not even the allowed 500 MW will be installed during 2009.

Of increasing importance for Spain's future PV market is the Technical Building Code (TBC), implemented since 2006, that established obligatory requirements to be met in the building sector. A section of the TBC regulates the incorporation of solar PV energy and enforces the installation of PV on new large buildings, such as offices, government buildings, hospitals and so on.

Sweden (SWE)

Annual installed PV power in Sweden in 2008 reached almost 1,7 MW – an increase of about 20 % compared with the market the previous year. Grid-connected distributed installations accounted for 84 % of the market. The cumulative installed power of PV systems in Sweden increased to 7,9 MW by the end of 2008. The share of grid-connected systems increased to 39 % of the total cumulative installed power from 27 % in the previous year. With few exceptions these projects were carried out with support from the investment subsidy for public buildings. The off-grid PV markets are quite stable with roughly 300 kW being installed each year.

The investment subsidy allowed for 70 % of project costs to be covered up to a maximum of 5 million SEK per building. The costs covered included materials, mounting and external project management costs for projects in buildings that are classified as special buildings or exempt from taxation by the property taxation law. This includes hospitals, churches, sports stadiums, schools, museums and practically any other building that is designated for public use or in conjunction with activities such as public transport. The subsidy programme, operating from the start of 2005 until the end of 2008, had a large positive impact on the installation of PV in Sweden. However, growth during 2008 was affected by reaching the programme total expenditure cap of 150 million SEK at the end of 2007. The cap was lifted in March 2008 and applications once again began flowing, but for smaller systems.

The programme has generally been viewed as a success, particularly for developing the interest of companies, municipalities, the public and the government. Property managers, municipalities and other actors have taken an interest in PV as a new method of alleviating their environmental impact. For example, Malmö city has embraced PV technology as a means of building a more sustainable urban environment. During 2008 several new PV plants were built in Malmö, with plans for further systems in 2009. Sege Park in Malmö is still the home of Sweden's largest PV installation, with an installed capacity of 166 kW. Another key stakeholder entering the PV market as a result of the subsidy scheme is Akademiska Hus, which owns and manages most university buildings in Sweden. During 2008 another three Akademiska Hus installations were completed, with a total installed capacity of 37 kW.

The outlook for 2009 and beyond is uncertain, following the finish of the subsidy programme at the end of 2008. There is currently a proposed new subsidy programme being reviewed by the European Commission that, if accepted, would grant a 60 % direct subsidy to PV installations on any type of building. However this has left the domestic market without any incentive to start or plan new projects for at least half a year. The proposed new scheme is very similar to the previous programme and would extend until end 2011.

Switzerland (CHE)

Annual installed PV power in Switzerland in 2008 reached 11,7 MW – almost twice the size of the market the previous year. Nearly all the systems installed were grid-connected and grid-connected capacity now makes up 92 % of Switzerland's cumulative installed PV capacity of 47,9 MW.

In 2007 the Swiss parliament adopted a revised Energy Act, including a preferential feed-in tariff scheme for renewable energies to commence at the beginning of 2009. However, during 2008 the Swiss

21.8 kWp PV System on a barn, Buochs, Switzerland

PV market was driven by the fact that the law on preferential feed-in tariffs would also apply to PV installations dating back to the start of 2006. A surcharge of up to 0,006 CHF/kWh is levied on end consumer electricity costs to fund the compensatory feed-in remuneration. This will bring in up to 320 million CHF per year and PV will be allocated 5 % of this amount, which corresponds to an installed capacity of 25 MW to 30 MW over time. The outlook is uncertain for the near future. It is anticipated that, while 2009 may have a larger annual market than reported for 2008, 2010 could see a dramatic decrease as a consequence of the federal allocation (cap). Consequently some cantons have started to think about their own preferential feed-in tariff schemes.

In addition to the measures promoted by the Federal Energy Act, the solar stock exchange schemes provided by several large electricity utilities are continuing to function well and it is expected that these will continue to provide an additional steadily growing market for PV. PV electricity is purchased for up to 0,75 CHF by regional electricity utilities for trading in these schemes.

Turkey (TUR)

About 750 kW of PV were installed in Turkey during 2008, with the annual market increasingly slightly from the stable level of the previous four years. Off-grid applications account for around 94 % of Turkey's cumulative installed PV capacity of about 4 MW.

The Turkish Government plans to increase the capacity share of wind and solar power generation from their current value of 0,5 % to over 10 % of installed electricity supply capacity by 2020. Amendments to the law in 2008 allow the connection of renewable energy plants up to 500 kW in size to the utility grid without needing special permission. The Ministry of Energy and Natural Resources plans to make the General Directorate of Electrical Power Resources Survey and Development Administration (EIE) responsible for defining technical criteria and the Energy Market Regulatory Authority (EPDK) responsible for evaluating the license applications of PV plants above 500 kW.

PV power is considered an important renewable energy source for Turkey as the country is geographically well situated with respect to solar energy potential. Throughout 2008, public interest in climate change and photovoltaic technology was quite high. Turkey has also ratified the Kyoto Protocol following an overwhelming vote in the national parliament early in 2009. A draft law that proposes support mechanisms for solar electricity has been brought before parliament in 2009 and is expected to be discussed in the Grand National Assembly of Turkey during 2010.

United Kingdom (GBR)

The annual installed PV capacity in the UK in 2008 was 4,4 MW, compared to 3,8 MW in 2007. The cumulative installed PV generation capacity increased by 24 % during 2008 reaching a total of 22,5 MW. The off-grid market is small; just over 100 kW were installed off-grid in 2008. Government funding through the Low Carbon Buildings Programme and other grants supported approximately 72 % of total new capacity.

In the UK the majority of PV installations are grid-connected distributed systems, installed on the roofs of domestic and non-domestic buildings. Building integrated PV (BIPV) is becoming increasing popular with the use of solar tiles which take the place of traditional roof tiles and also the use of PV in facades, louvres and canopies. Systems are typically small: 1 kW to 3 kW for domestic installations or 5 kW to 30 kW for non-domestic installations on average. The largest system in the UK to date is the 391 kW PV façade on the CIS tower in Manchester.

The Low Carbon Buildings Programme (LCBP), funded by the Department of Energy and Climate Change (DECC), provides grants to support installations of microgeneration technologies including PV for householders, community organizations, schools, the public sector and businesses. The programme is UK-wide and aims to demonstrate how energy efficiency and microgeneration will work hand in hand to create low carbon buildings. A total of 80 million GBP was announced initially for the three year programme running from 2006. Under Phase 1 householders' PV installations are eligible for a maximum of 2 000 GBP/kW of installed capacity, subject to an overall maximum or 50 % of the relevant eligible costs, whichever is the lower – grant applications to the householder stream dropped dramatically after the maximum grant was capped at 2 000 GBP in May 2007. PV has proved to be a popular technology accounting for over 50 % of the grant funding awarded under Phase 2, which

supports installations for community organizations, including schools. In December 2008 an additional 7 million GBP were made available for PV installations under Phase 2 of the programme. Over 40 % of the 1 032 projects involved installations on schools.

Other programmes in operation are Reconnect in Northern Ireland, where energy is the responsibility of the Northern Ireland Assembly, and Switched on Schools, a partnership of Northern Ireland Electricity, the Department of Agriculture and Rural Development and the Education and Library Boards. In addition to the government grant programmes 'top up' funding is available from a number of sources. This is often used as matching funding to the government grant funds resulting in an almost free PV system for some customers. Additional funding sources in 2008 included the Community Sustainable Energy Programme, Northern Ireland Electricity, EDF Green Fund, E.ON Sustainable Energy Fund, Green Energy Trust, and the Co-operative Group.

In October 2008 the UK parliament published amendments to the Energy Bill to enable two renewable feed-in tariffs: one for electricity and one for heat and biogas, with an upper threshold of 5 MW. It is anticipated that the electricity tariff will be introduced in April 2010. From April 2009 banding will be introduced to the Renewables Obligation, providing differentiated levels of support to the various technologies in order to encourage a larger contribution from emerging renewable technologies. PV will receive two Renewables Obligation Certificates per MWh generated. During 2008 the Renewables Obligation was extended by 10 years to 2037. The Environmental Transformation Fund (ETF) began operation in April 2008 with the aim of accelerating the commercialization of low carbon energy and energy efficiency technologies.

In May 2008 the Code for Sustainable Homes became mandatory in England (originally launched as a voluntary measure in 2006). The code uses a 1 to 6 star rating system to mark the sustainability performance of a new home against nine categories of sustainable design including energy. All new homes must attain at least a level 3 rating and the higher levels of the code require the installation of microgeneration technologies such as PV. From October 2008 all buildings, whenever sold, built or rented, need an Energy Performance Certificate (EPC). The certificate provides energy efficiency ratings and recommendations for improvement. Large public buildings were required from October 2008 to have on public view a Display Energy Certificate (DEC) showing the building's energy efficiency rating, based on the energy consumption of the building as recorded by gas, electricity and other meters. At present there are no minimum rating/requirements that a building has to reach however it is thought that a low energy rating may lower the value of a building. The inclusion of a renewable technology such a PV improves the energy performance of a building.

United States of America (USA)

Total PV capacity in the US increased by an estimated 338 MW in 2008 – representing growth in the annual market of about 64 % compared to the previous year. Of this market 87 % (293 MW) were grid-connected systems and 13 % (45 MW) were off-grid installations. Cumulative installed capacity in the US reached 1 168 MW by the end of 2008.

In 2008, 270 MW of grid-connected distributed PV systems (77 MW residential, 193 MW non-residential) were installed. The States that led in new grid-connected PV installations during the year were California (182 MW), New Jersey (22 MW), Colorado (22 MW), Nevada (15), and Hawaii (9 MW). According to the Solar Electric Power Association (SEPA) by the end of 2008 there were over 70 000 distributed PV systems interconnected across the country. Utility-scale PV power plants, the largest of which has an installed capacity of 14 MW, account for over 5 % of US cumulative installed PV capacity.

The US Federal Investment Tax Credit (ITC) legislation had a great impact on the PV market during 2008. Anxiety over the possible expiry of the ITC at the beginning of 2009 encouraged a rush by businesses and consumers to install systems using the existing credits. In October 2008 the Emergency Economic Stabilization Act of 2008 was passed that extended the 30 % commercial ITC until end 2016, eliminated the monetary cap for the ITC applied to residential PV installations and allowed utility companies and alternative minimum tax filers to make use of the tax credit.

Throughout 2008 the US Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Programme conducted programmes to develop pilot production of innovative cell technologies, brought cross-cutting PV products to market and promoted advanced electricity grid developments to accommodate high capacities of PV generation. Hundreds of PV systems were installed across the country through the DOE Solar America Initiative (SAI), which provides funding and technical assistance to cities, states, and federal agencies for PV applications. These included large-scale PV installations of more than 100 kW. SAI inaugurated 25 Solar America Cities dedicated to accelerating the adoption of solar energy at the local government level.

Thirty two states and the District of Columbia had renewable portfolio standards (RPS) in place during 2008, and five states have voluntary standards. Most states with RPS promoted solar technologies, and 13 states and the District of Columbia included a specific PV requirement. Feed-in tariffs were offered for the first time in 2008, at the state and city government level. California is considering changes

9.5 Grid Connected PV System at the Regional Wind Technology Center Oaxaca, Mexico

that would expand applications of its feed-in tariff, and other states, including Hawaii and Wisconsin, are considering feed-in tariffs to promote PV. The first city feed-in tariff was approved by Gainesville, Florida, to take effect in 2009. The city-owned Gainesville Regional Utilities proposed paying 0,32 USD/kWh for PV electricity, which could provide a 3 % to 5 % return on investment for residential or business customers participating in the programme. Other cities, including Los Angeles, have proposed feed-in tariffs for 2009.

Almost three-quarters of non-residential PV installations in 2008 were driven by third-party financing and Power Purchase Agreements (PPAs). With PPA financing, commercial customers supply a rooftop or other property to host the PV system and agree to purchase the electricity generated at a specified rate (usually at or below current retail electricity rates) for a long term (20 years). Residential installations also benefited from third-party and PPA financing. Community group purchases by the company 1 Block Off the Grid (1BOG) negotiated up to 48 % off the market price of 2 kW PV systems for its participants in San Francisco during 2008. Other programmes such as Go Solar Michigan of the Great Lakes Renewable Energy Association and Go Solar Marin have offered group purchases for several years. Partnerships between PV suppliers and large employers are offering the option to buy discounted residential PV systems as an employee benefit.

Important utility-scale PV projects were completed in 2008, supported by federal, state, and local government incentives. The Sacramento Municipal Utility District (SMUD) created the innovative SolarShares programme, which allows customers in the SMUD territory to purchase local 100 % PV electricity, offering 'ownership' of a share of the generation from a local plant. SMUD both contracts for renewable electricity from independent power producers as well as building and owning renewable energy plants. Similar green pricing programmes have been announced in other cities, including Los Angeles, to increase renewable electricity generation and reduce greenhouse gas emissions. Electricity utilities are expected to play a much larger role in deploying PV in 2009. This is because the extension of the ITC now allows the utilities to apply for the 30 % tax credit. Even in the uncertain economy of early 2009, many utilities were actively planning large PV power projects to meet their generation needs.

Other countries

Verifying total market volume and other data for non IEA PVPS countries is challenging, 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.

China

Whereas China's PV manufacturing capacity has increased exponentially in the past five years, pushing the country to the number one position amongst PV producing countries, domestic implementation of PV systems has been relatively 'underwhelming'. Traditionally PV has served an important but nonetheless relatively niche role in China as a means of providing off-grid electricity or power to mini-grids in less developed parts of the country.

Targets for national deployment do exist; by 2010, the government anticipates a total of 300 MW of PV will be installed, of which 220 MW is for 'generating capacity' as opposed to consumer products. From the present base of 120 MW to 140 MW (between 20 MW and 40 MW were added during 2008), that target seems readily achievable given the massive excess production capacity that currently exists in China. This under-utilized production – caused predominantly by the significantly reduced demand for modules from Spain and delays to international projects in the wake of the global economic downturn - may be the stimulus for more substantive domestic implementation initiatives. PV manufacturing in China is increasingly big business, and the central government is evidently coming to appreciate that, without a strong domestic market, Chinese producers will be heavily exposed if demand from overseas fails.

During 2008, the only ongoing coordinated government initiative of significance came under the National Development and Reform Commission's call for eight large-scale PV power stations (typically 5 MW to 10 MW each) to be constructed in the western provinces. However, 2009 has seen a step-change in government activity at both central and (certain) provincial levels. Perhaps significantly this has included concrete policies emanating from the Ministry of Finance and Construction (MoF), rather than the development planning approach that has

typified China's domestic PV actions to date. Firstly, in April MoF hastily announced a subsidy for rooftop and building integrated PV systems. A level of 20 CNY/W (approx 2,10 EUR/W) was set for BIPV, which would equate to the order of 50 % investment subsidy for typical projects. As a result, by mid-year, Photon International was reporting its awareness of close to 2 GW of proposals 'floating around'. Subsequently the Jiangsu Provincial Government has announced a feed-in tariff aiming at 400 MW of PV to be installed in the province up to 2011. The tariff rates for 2009 are certainly attractive enough to stimulate interest among project developers – up to 4,3 CNY/kWh (0,38 EUR/kWh) for BIPV with slightly lower rates of 3,7 CNY/kWh and 2,15 CNY/kWh for rooftops and ground-mounted systems respectively (although the term of the fixed rate contract was not clear at the time of writing). This is believed to be a precursor to a nationwide feed-in tariff scheme that would underpin and be supplemented by additional Provincial funds.

In the light of these developments the stated target of 1,2 GW of installed PV by 2020 now looks to be rather unambitious and China has the potential to put even the accomplishments of the best established IEA PVPS markets rapidly in the shade.

Ethiopia

At the other end of the scale, small solar PV systems continue to deliver transformational energy services to families and communities in remote areas particularly in less developed countries. An example is the German charity, Stiftung Solarenergie, which was recently recognized for its efforts to bring affordable lighting to communities in rural Ethiopia.

The package consists of a 10 W PV module, battery and controller, sufficient to power up to four LED lights for several hours per day. To date, capital costs of the systems have been financed by donations, while households themselves pay approximately 0,75 EUR per month to cover maintenance and component replacement. As the rollout continues, the intention is to offer loans to families to achieve full cost recovery based on monthly repayments similar to typical expenditure on kerosene and dry cell batteries.

Over 2 100 SHS have been installed in two villages up to the end of 2008, benefiting some 10 000 people. A further 8 500 systems are targeted to be delivered during 2009.

European Union – Non-PVPS Countries (including Belgium, Czech Republic & Greece)

A detailed analysis of a range of indicators relating to PV (and other Renewable Energy Sources) in the European Union Member States is undertaken annually by the Observatory of Renewable Energies via its 'EurObserv'ER barometer'. The barometer is currently monitoring across all 27 Member States, including the two newest members. As regards EU Member States that are not presently participating in the IEA PVPS programme, the barometer indicates that some 183 MW were installed in those countries to the end of 2008. This equates to slightly less than 2 % of the EU total including PVPS countries.

While their relative contribution to the EU total appears rather insignificant, the picture is heavily distorted by Germany and Spain's influence on the PVPS component. On closer inspection, the fifth largest national total installed within the EU zone is in Belgium (71,2 MW); only Germany, Spain, Italy and France can claim more installed capacity. The surge in PV installations in Belgium (EurObserv'ER estimates almost 50 MW were added in 2008 alone) is largely due to the very rewarding production incentives that are available. These mean that in certain parts of the country PV system owners can see an effective value of over 0,60 EUR/kWh guaranteed for twenty years. Additional tax incentives and grants can give rise to simple internal rates of return exceeding 15 % at the present time.

While PV in Belgium is clearly booming, the Czech Republic actually installed more new generation capacity in 2008 (50,3 MW), putting it fifth in terms of annual PV installations in the EU behind only Spain, Germany, Italy and France. This represented a twelve-fold increase compared to the previous year. Again the market growth has been coupled to a very favourable production incentive (a feed-in tariff equivalent to approximately 0,50 EUR/kWh up to the end of 2008, guaranteed for 20 years) and income tax exemptions. Certain public sector and charitable organizations may also be eligible for additional capital subsidies of up to 40 % for building integrated installations, as a result of European Structural Funding.

Greece also registered a noteworthy year as regards PV installation, adding more than 9,3 MW in 2008 to effectively double its installed capacity. While 2008 showed some potential, there are strong expectations that the market will expand considerably again from 2009 onwards, following the introduction of a new tariff scheme that initially guarantees producers as much as 0,50 EUR/kWh for a 20 year period for large-scale systems. At the smaller end of the scale systems under 10 kW can expect a tariff of up to 0,55 EUR/kWh from the middle of 2009.

India

India remains the only country in the world with a Ministry explicitly focused on New and Renewable Energy. To date MNRE programmes have reportedly resulted in the installation of an estimated 5 MW of street lighting systems, 450 000 home lighting systems, 730 000 solar lanterns and over 7 000 PV pumps. Nonetheless, given the large number of small systems involved, it is extremely challenging to arrive at an accurate figure for the total installed capacity.

Estimates by the European PV Industry Association suggest that some 28 MW of new PV capacity were installed in India in 2008, corresponding to a total installed capacity of over 160 MW. This keeps India marginally ahead of China for a further year at least as the non-PVPS country with the largest capacity of installed PV generation plant.

The progress in 2008 – similar to 2007 - was rather disappointing given that MNRE established a feed-in tariff for electricity generated from solar energy at the beginning of the year. At a maximum of 15 INR/kWh (< 0,25 EUR/kWh) guaranteed for no more than 10 years and capped at 50 MW of capacity, the incentive has not provided a framework for significant expansion of the Indian market. However, the situation may change from 2009 onwards. One reason for optimism is that State governments may also offer discrete support for PV. At the start of the year, Gujarat – the birth State of Mahatma Gandhi - announced its Solar Power Policy 2009 initiative, targeting installation of 500 MW of solar power plant over the next five years. The total capacity accommodates both solar thermal and PV technologies. The basic tariff rate is not more rewarding than the national government's 2008 FiT, however the duration of the incentive payments is much greater, coupled to which the State's electricity companies are obliged to buy the power.

Additionally, the national government is reportedly preparing a 'National Solar Mission' which may target as much as 20 GW of solar capacity (PV and thermal) by 2020. Significant funding issues would need to be overcome to achieve such a goal. But India – like China – has ambitions to capture a significant share of the global solar manufacturing industry and this is unlikely to be achieved in the absence of a significant domestic market.

Singapore

The Singapore Government has ambitions to build the nation into a 'Clean Energy Hub' and has already been successful in attracting significant investment from major international PV businesses to establish manufacturing capacity in the country. On the implementation side, a 'Solar Capability Scheme (SCS)' has been initiated providing up to one million SGD (30 % to 40 % of the total capital cost of PV projects) for projects promoting innovative design and integration of solar technologies into energy efficient buildings

United Arab Emirates

As noted in the 2008 Edition of Trends in PV Applications, Masdar City is intended to be the world's first carbon-neutral city – to be built from the sand up in the desert of the Emirates. The city is to be largely powered by 'home grown' PV. Initially a requirement for 200 MW is anticipated, to be embedded in the envelope of buildings across the city. The first stage of these ambitions saw the construction of a 50 MW thin film plant in Germany, but subsequent lines will be built in Abu Dhabi itself over the next few years.

Mirroring the blooming of this city from scratch, Abu Dhabi's rulers also have ambitions to develop solar manufacturing capacity largely from first principles. A silicon production capacity of 6 000 tonnes has been promised, with cell and module production capabilities of 800 MW per year scheduled to be online by 2012.

1.4 R&D activities and funding

The public budgets for research and development in 2008 in the IEA PVPS countries are outlined in Table 4. The 2008 total expenditure of about 425 million USD represents an increase of almost 30 % over the R&D expenditure in 2007. The most significant countries in terms of expenditure are the US, Germany, Korea and Japan. France, the Netherlands, Spain and the UK also demonstrated a strong commitment to R&D activity. Switzerland and Norway, both with increasing R&D budgets, are interesting because of the size of the countries and the level of investment in R&D compared to their other PV activities. The reader is directed to the individual national survey reports on the public website for a comprehensive summary of R&D activities in each of the countries. A brief overview of the activities in key countries is presented below.

A clear leader in terms of R&D public funding, the US Department of Energy (DOE) PV R&D Programme's goal is to develop reliable PV systems with lifetime energy costs competitive with electricity from conventional sources. The PV Programme funds work to 1) increase the sunlight-to-electricity conversion efficiency and performance of PV cells, modules, and systems; 2) reduce the manufacturing cost of PV cells, modules, and balance of systems; 3) reduce the installation, interconnection, and certification costs for residential, commercial and utility systems; and 4) increase system operating lifetime and reliability. The National Renewable Energy Laboratory (NREL) and Sandia National Laboratories (Sandia) are the major national laboratories supporting the PV Programme. In 2008, the PV Programme expanded the Solar America Initiative to focus on technology pathways most likely to reach cost competitiveness by 2015. Results of the DOE PV R&D Programme in 2008 ranged from new, highly-efficient PV cell designs to new processes for high-volume manufacturing of PV materials. In 2008 The PV Incubator Project was launched to help start-up PV companies work with the national laboratories to make module prototypes and pilot manufacturing processes, as was University PV

Process and Product Development Support, which aims to apply the special capabilities of the universities through competitively awarded, university-led process and product development projects.
In Germany, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) provided almost 40 million EUR for 130 PV R&D projects in 2008. The focal point remains wafer based silicon technologies (59 % of the budget), followed by thin film technologies (32 %). In addition, the development of system technology, alternative technologies such as concentrating PV and crosscutting issues are funded. The Federal Ministry of Education and Research (BMBF) also supports R&D on different aspects of PV. In 2008, the BMBF published its concept paper 'Basic Energy Research 2020+' and has promoted a joint initiative of BMBF and industry to address the development of organic solar cells and networks for assisting the development of thin film PV cells. BMBF places an emphasis on topics such as material science including nanotechnology, new experimental or analytical methods and synergies with other fields of research such as microelectronics and bionics.
Korean R&D funding in 2008 showed an almost three-fold increase over 2007 funding, resulting in Korea now having the third highest R&D expenditure of the IEA PVPS countries. From 2008, Korea Energy Technology Evaluation and Planning (KETEP) has assumed the lead role in Korea's PV R&D programme. The government's new R&D strategy is composed of four programmes: Strategic Technology Programme, Breakthrough Technology, Core Technology, and Demonstration and Planning Programme. Only Breakthrough Technology is led by universities or research institutes. The other programmes are industry-led. The newly launched four main projects under the Strategic Technology Programme are: Low-cost large-area Si thin film PV modules, Glass substrate CIGS thin film PV modules, Low-cost, high-efficiency crystalline silicon solar cells and manufacturing equipment, and Manufacturing equipment for solar grade polycrystalline silicon feedstock.
In 2008, Japan's 'Four-Year Plan for Photovoltaic Power Generation Technology Research and Development', which commenced in 2006, continued two major projects by the New Energy and Industrial Technology Development Organization (NEDO) – R&D of Next-generation PV Generation System Technologies, and PV System Technology for Mass Deployment, Phase II. Development of Technologies to Accelerate the Practical Application of Photovoltaic Power Generation Systems commenced in 2008, and Research and Development on Innovative Solar Cells (International Research Center for Innovative Solar Cell Programme) was launched. 2008 saw the continuation of Verification of Grid Stabilization with Large-scale PV Power Generation Systems and Development of an Electric Energy Storage System for Grid-connection with New Energy Resources. Basic research projects (including PV technological development) were planned and public proposals invited by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), previously conducted mainly by the Ministry of Economy, Trade and Industry (METI).

2008 marked the second year of the European Union's 7th Framework Programme which will operate until 2013. A FP7 2008 call for proposals was carried out and a highly-ranked activity concerns a demonstration of the electrical benefits from PV on a large scale – in particular increasing the power quality and security of system operation in a residential area, and the security of supply and autonomous operation in an industrial zone.

Table 4 – Public budgets for R&D in 2008 in selected IEA PVPS countries

Country	Million EUR	Million USD
AUS	4,20	6,18
AUT <2007>	1,59	2,34
CAN	1,56	2,29
CHE	9,2	13,5
DEU	59,4	87,4
DNK	3,3	4,9
ESP	12	17,6
FRA (ANR, ADEME)	12	17,6
GBR	14,8	21,8
ISR	0,24	0,35
ITA	5	7,4
JPN (METI)	24,33	35,78
KOR	35,92	52,83
MEX	0,32	0,47
NLD	12	17,6
NOR	6,7	9,9
SWE	3,0	4,4
USA	83,3	122,5

2 The PV Industry

This section provides information on the industry involved in the production of PV materials (feedstock, ingots, blocks/bricks and wafers), PV cells, PV modules and balance-of-system components (charge regulators, inverters, storage batteries, mounting structures, appliances etc.) during 2008. Three steps along this supply chain - production of the upstream materials, PV cell production and final manufacture of PV modules - each account for roughly one third of the cost of finished PV modules.

A national overview of PV material production and cell and module manufacturing in the IEA PVPS countries during 2008 is presented in Table 5 and is directly based on the information provided in the national survey reports. This likely accounts for at least one half of the worldwide production, down from approximately two-thirds in 2007, about three-quarters in 2006 and at least 90 % previously. Reflecting this trend, 2008 produced one very interesting reversal in global PV industry / market dynamics. Over the last decade or so in the IEA PVPS countries, each year's installed market capacity expressed as a percentage of total module production has ranged from 63 % in 1998 to 88 % in 2004, settling at around 84 % to 86 % in the period 2005 to 2007. However, in 2008, installed market capacity in the IEA PVPS countries exceeded module production by close to 40 %.

Large and successful players in the PV supply chain are, by necessity, becoming increasingly multinational in their operations. A prime example is Norway's Renewable Energy Corporation (REC) which produces PV cells and wafers in Norway, silicon feedstock in the US, PV modules in Sweden, operates an integrated solar manufacturing complex in Singapore and has long-term supply agreements in place with countries such as Taiwan. With time it would be expected that the smallest businesses may disappear altogether, the small to medium players get absorbed by large multinationals or specialize in PV niche markets and vertical integration of the industry is the norm. The global financial downturn and tighter access to investment capital will only serve to accelerate this trend.

Table 5 – Production of PV materials, cells and modules in 2007 in selected IEA PVPS countries

Country	Solar PV grade Si feedstock production (tonnes) ***(1)***	Production of ingots & wafers (MW) ***(1) (2)***	Cell production (all types, MW)	*Cell production capacity (MW/year)*	Module production (MW) ***(3)***		*Module production capacity (MW/year)*
					wafer based (sc-Si & mc-Si)	thin film (a-Si & other)	
AUS	-	-	42	*44*	8	-	*10*
AUT	-	-	-	-	65,4	-	*na*
CAN	1 200	-	-	-	26	0,4	*100*
CHE	-	~120	<1	*na*	11,5	<1	*na*
DEU	11 200	>710	1 513	*2 339*	914	289	*2 148*
DNK	-	~1	-	-	0,5	-	*0,5*
ESP	-	>92	195	*260*	498	-	*891*
FRA		117	60	*60*	~120	0,7	*~125*
GBR	-	230	2,5	*5*	225,5	2,5	*263*
ITA	-	-	28,4	*105*	144	-	*333*
JPN	>1 680	>465	1 227,5	*1 722*	>468	100,3	*>925*
KOR	not available (na)	>76	67,4	*166*	106,1	8,3	*320*
MYS	-	-	167	*392*	-	167	*392*
NOR	na	>622	na	*225*	-	-	-
PRT	-	-	na	*5,5*	28,4	na	*120,5*
SWE	-	-	-	-	185	-	*239*
USA	25 787	174	429,7	*665,6*	161,7	267	*665,6*
Estimated Total	**>40 000**	**>>2 650**	**>3 740**	***5 990***	**>>2 970**	**~840**	***>>6 600***

Notes: (1) Although some IEA PVPS countries are reporting on production of feedstock, ingots and wafers, the picture from the national survey reports of these sections of the PV industry supply chain is not complete and consequently these data are provided more as background information. (2) 12 tonnes of ingot are equivalent to 1 MW of PV cells (3) mc-Si (multicrystalline silicon) includes modules based on EFG and String Ribbon cells. 'Other' refers to technologies other than silicon based. The total module production and module production capacity data for some countries were not available.

The production of specialized equipment for the PV manufacturing industry has become a significant business in its own right. Activities and products in this sector of the PV industry value chain include chemical and gas supplies, abrasives and equipment for cutting wafers, pastes and inks for cells, encapsulation materials for modules and specialized measurement equipment for use in production processes.

2.1 *Feedstock, ingots and wafers (upstream products)*

Crystalline silicon wafers remain the dominant substrate technology for making PV cells and, for the time being, the discussion in this section does not refer to thin film technologies. Although some IEA PVPS countries are reporting on production of feedstock, ingots and wafers, the picture from the national survey reports of these sections of the PV industry supply chain is not complete and consequently this section is provided more as background information.

Feedstock

Today, the main source of silicon feedstock for PV cells is virgin polysilicon. 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, these new materials have not yet been introduced to the market.

In 2008, as reported in previous Trends reports, solar photovoltaic grade silicon feedstock supply remained dominated by the three major producing countries: Germany, the US and Japan, with Canada now also reporting production by Bécancour Silicon Incorporated. The other major feature of interest in 2008 was the dramatic (five-fold) increase in production in the US - with Hemlock Semiconductor Corporation, Renewable Energy Corporation and MEMC together accounting for over 92 % of US production, of which 85 % is exported. The US provided more than half the solar photovoltaic grade silicon feedstock used in the IEA PVPS countries.

The key current production countries have all reported new entrants preparing to enter the market. Germany, for example, anticipates that in 2009, at least four companies will be active. Other IEA PVPS countries including Korea, Norway, France, Italy and Spain have flagged significant developments. For example, in 2008 Norwegian Elkem ASA, a world

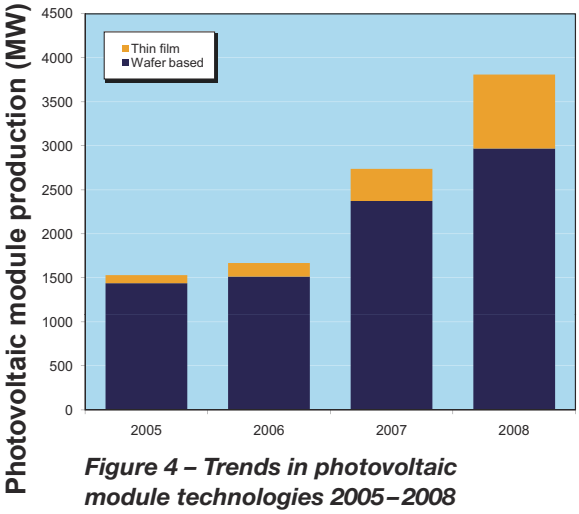

Figure 4 – Trends in photovoltaic module technologies 2005–2008

leading supplier of metallurgical grade silicon, through its division Elkem Solar has commissioned a new plant for the production of high-purity silicon for PV cells at Elkem Fiskaa in Kristiansand. Production will be ramped up during 2009 and the total capacity will be about 6 000 tonnes of silicon feedstock. Many other newcomers (for example, numerous companies in China alone) have also announced plans to enter the feedstock silicon business. However some potential entrants are expected not to proceed due to a limited availability of venture capital.

Ingots and wafers

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 directly to wafers of desirable size. Silicon ingots are of two types: single crystal and multicrystalline. The first type, although with different specifications regarding purity and specific dopants, 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.

Norwegian, German, British and Japanese companies feature most prominently in this section of the industry value chain. Other countries reporting activities include Switzerland, Denmark, Spain, France, Korea and the US. Some companies are vertically-integrated, controlling the process from ingots to cells and modules. Norway's REC Wafer produces single crystal and multicrystalline ingots and wafers at two locations in Norway, Glomfjord and Herøya. Wafer production increased by 15 % to 582 MW in 2008. The REC Wafer division had about 950 employees at the end of 2008 and the total production of wafers is expected to exceed

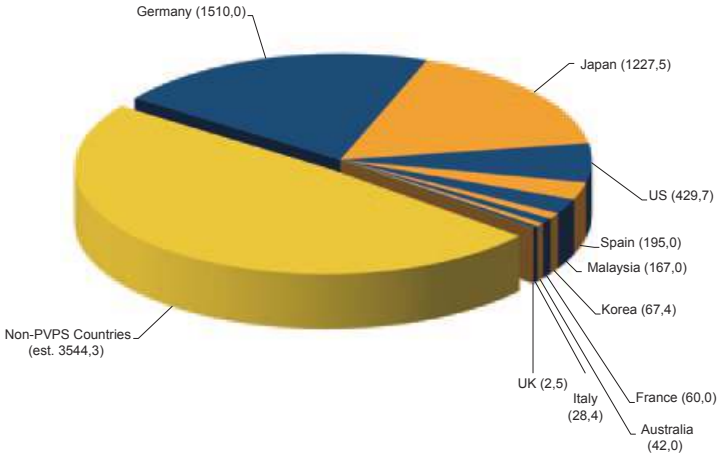

Figure 5 – World PV cell production (MW) by country in 2008

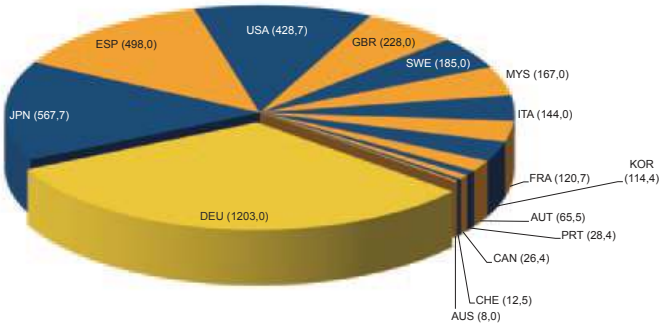

Figure 6 – PV module production (MW) by country in 2008

1 000 MW in 2009. REC Wafer has approximately 15 external customers including BP Solar, China Sunergy, Gintech, Mitsubishi, Motech, Moses Baer, Photovoltech, Q-Cells, Sharp, Solland, Suniva and SunTech. In Germany the main supplier of silicon wafers is still Deutsche Solar AG in Freiberg. In addition to this company there are at least five significant German wafer manufacturers such as PV Silicon at Erfurt and Ersol (formerly ASI) at Arnstadt. Japan's M.Setek, SUMCO and JFE Steel manufacture silicon ingots and wafers for supply to PV cell producers. Kyocera manufactures silicon ingots and wafers at its own manufacturing facilities. The UK's Crystalox Limited is one of the world's largest producers of multicrystalline silicon ingots, exporting to PV companies in Europe and Japan. Ingots and wafers are produced in Switzerland and France and wafer production is reported in the US.

2.2 *Photovoltaic cell and module production*

The total PV cell production volume for 2008 in the IEA PVPS countries was reported to be at least 3 740 MW, up from 2 400 MW in 2007, an increase of 56 %. The largest increase in production took place in Germany (which came close to doubling its production to about 1 500 MW) while Japan's production increased by 33 %.
Germany replaced Japan as the leading producer of photovoltaic cells during 2008. Production of cells and modules in this country accounted for 40 % and 22 % respectively of the IEA PVPS countries' production, with Japan in second place with 30 % and 19 % for shares of cell and module production respectively. In the United States, the third largest PV cell producing country, production increased by 62 % from 2007. Spain's module production occupies the third position during 2008. US output of thin film technologies increased by over 50%, while Germany's thin film production tripled – between them these two countries represented two thirds of world thin film production in 2008.

Cell production in Germany showed steady growth, with twelve companies engaged in 2008. Q-Cells in Thalheim was the largest cell producer in Germany and also worldwide. There are now more than 15 module production companies with a production capacity of more than 1 MW. Amongst these, the largest are Aleo Solar, Solar Factory, Solarwatt and Solon, all with a production capacity of 100 MW or more. An increasing number of companies have invested in thin film production lines – 11 companies are operating or building production facilities for silicon thin film modules, 12 companies are involved in CIS production and CdTe modules are currently fabricated by two companies. It is expected that, from 2009, thin film technologies will have a production capacity of more than 1 000 MW, half of the module production capacity of silicon wafer technologies. In Japan during 2008, 11 companies were listed as PV cell / module manufacturers: Sharp, Kyocera, Sanyo Electric, Mitsubishi Electric (MELCO), Kaneka, Mitsubishi Heavy Industries (MHI), Space Energy, Fuji Electric Systems, Honda Motor, Showa Shell Sekiyu and Clean Venture 21. Space Energy took over Hitachi's business of manufacturing bifacial silicon PV cells. Fuji Electric manufactures flexible a-Si PV modules, Honda Motor and Showa Shell Sekiyu manufacture CIGS PV modules and Clean Venture 21 manufactures spherical Si PV modules. Manufacturers specializing in PV modules include MSK (now renamed Suntech Power Japan after acquisition by Suntech Power Holdings in China), Fujipream, and YOCASOL which was established through an employee buy-out. The US reported an increase in domestic PV manufacturing capacity by

65 % to 685 MW of capacity in 2008. The largest US PV companies in 2008 by module shipment were First Solar, United Solar, Solar World, BP Solar and Evergreen Solar. Of about 100 active PV cell and module manufacturers in North America, 72 are seen as start-ups that are bringing innovative technologies to market. Venture capitalists invested almost 1 600 million USD in PV companies in the third quarter of 2008 alone. Companies developing thin film modules using CIGS or CdTe received some of the largest rounds of investments. The following PV companies opened new manufacturing facilities in 2008: EPV Solar, Global Solar Energy, HelioVolt, Konarka Technologies, Miasolé, Nanosolar, SolarWorld, Solon AG and Suniva Inc. Spain reported healthy growth in 2008 amongst its four cell producers – BP Solar Spain, Isofoton, Guascor Foton and Sol3G – and its 21 module producers.

A number of other countries reported significant PV cell / module production stories in 2008. Malaysia, through the establishment of several key PV foreign direct investments (FDIs), has begun producing PV modules. These PV FDIs include First Solar Inc, Q-Cells AG, Sunpower Corporation, Renesola Ltd and Tokuyama Corporation. Canada reported a 58 % increase in full-time labour places in the manufacturing sector (modules, BOS and silicon feedstock) above 2007 levels. In the UK, Sharp's module assembly plant in Wrexham produced 206 MW of crystalline PV modules, Romag's Building Integrated Photovoltaic (BIPV) laminating facility in Consett produced 19 MW, Epod Solar Wales manufactured thin film amorphous silicon cells and modules at its factory in Bridgend and G24 Innovations Ltd produced dye sensitized solar cells (DSSC) on a commercial scale at its facility in Cardiff, Wales. Korea reported significant growth in production across the whole supply chain. In particular four companies including three new entrants produced 59 MW of crystalline silicon PV cells, seven companies produced about 106 MW of crystalline silicon PV modules (total annual production capability of 300 MW) and one company launched production of a-Si thin film PV modules, with a production volume of 8,3 MW and a capacity of 20 MW. Sweden also reported a significant growth in production amongst its five module producers, although the supply of cells was sometimes a limiting factor for production during 2008. In total 185 MW of modules were produced during 2008, a 164 % increase over 2007 production levels. Since the Swedish PV market is small the module companies export almost all production and are strongly dependent on the state of the European market.

In 2008 wafer-based crystalline silicon technologies maintained their dominance, accounting for about 78 % of the market for PV modules in the IEA PVPS countries. However, this percentage has slipped a further nine percentage points from 2007, following a loss of four percentage points the previous year. This is due to thin film technologies steadily increasing their share of an expanding market. Total module production increased by almost 50 % from 2007, following similar growth the previous year.

A small solar tracker project, Turkey (Courtesy: Ekosolar Ltd.)

The cell production capacity in the IEA PVPS countries, defined as the maximum output of manufacturing facilities, increased by about 58 %. Utilization of capacity was about 62 %, similar to the previous three years and down from a high of 86 % in 2004. Module production capacity increased by around 80 % and the utilization of capacity approached 60 %. 2008 provided some interesting growth stories in individual countries and also at the global level. The reader is directed to the individual national survey reports for a comprehensive summary of manufacturers and production in each of the countries. Some common themes identified in previous years still seem to apply to the PV industry in 2008, to a varying degree:

- cell supply shortages still created difficult circumstances for some module producers but this appears to have eased (at least in some countries);
- foreign product and price offers are increasingly impacting domestic markets;
- access to a booming foreign market provides an ongoing lifeline for the industries in some countries where the domestic market has slowed appreciably.

IEA PVPS does not undertake direct assessment of production developments in countries not participating in the IEA PVPS Programme. As in previous years, this summary presents a brief analysis of other industry commentators' findings in relation to production throughout the rest of the world.

A notable difference from last year's summary is the recognition of the difficulty of gathering reliable

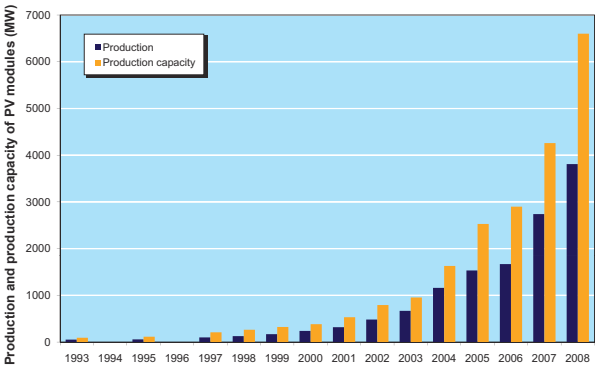

Figure 7 – Yearly PV module production and production capacity in the IEA PVPS reporting countries

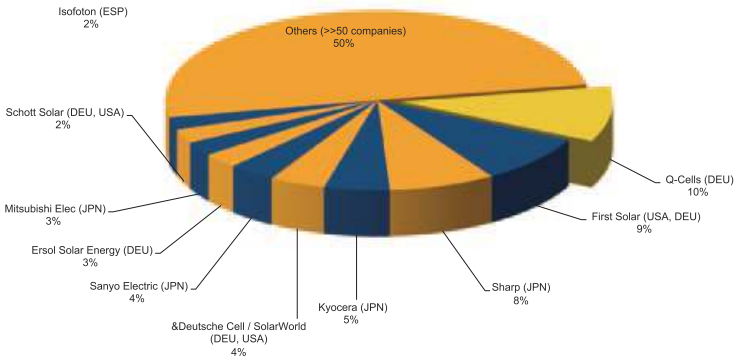

Figure 8 – Share of PV cell production in the IEA PVPS reporting countries by company in 2008 (%)

information on global PV module production. This is largely a result of the combined effects of a rapid explosion in the number of new market entrants in recent years, making first-hand data collection extremely arduous, and also a reflection of reporting sensitivities in the light of the global economic downturn and the recent downturn in demand for modules from key markets (notably Spain). Nonetheless, PV cell production data are still reported with a good degree of confidence and again the importance of manufacturing outside of the IEA PVPS countries is obvious.

Photon International, for example, reports that some 3 900 MW of PV cells were manufactured outside of PVPS countries in 2008. Again, some manufacturers reported production for the year equivalent to 100 % of their production capacity as installed at the end of 2008; while these data must be treated with a degree of caution, the number of companies reporting obviously spurious data has apparently declined since the 2007 survey. All the same, there remains a wide variation in the figures reported by different sources. PV News, for example, is much more conservative, particularly in respect of the Chinese PV cell manufacturing, which it assesses at approximately 1 790 MW compared to Photon's 2 550 MW. This would result in a more tempered figure for total cell production outside the IEA PVPS countries of approximately 3 010 MW. Despite the variations, there does appear to have been further relative penetration of non-PVPS countries' PV cell production to between 44 % and 50 % of the global total, up from close to 42 % in 2007.

Irrespective of the data source, China has cemented it's position as the world's leading producer of PV cells accounting for at least 23 % and possibly as high as 37 % of the global PV cell manufacture in 2008. Taiwan accounted for some 830 MW to 900 MW of cell production, consolidating its position at number four in terms of national production behind China, Germany and Japan. The Philippines increased its PV cell production to 237 MW, sufficient for sixth position behind the US in a global list of cell production in 2008. Three mainland Chinese companies as well as one Taiwanese and one Filipino firm would register on a global top 10 of PV cell manufacturers. One notable announcement in early 2009, reflecting future market expectations and the continuing globalization of PV production, was the reported intent of China's largest cell manufacturer to establish a major manufacturing facility in the USA. Upstream in the PV industry supply chain, China's solar photovoltaic grade silicon feedstock production capacity was estimated to have seen a five-fold increase in 2008 to 5 000 tonnes/year, compared to 2007 (1 000 tonnes/year). Industry analysts expect that this will expand to 20 000 tonnes/year by 2012.

2.3 *Balance of system component manufacturers and suppliers*

From a cost perspective, balance of system (BOS) components account for between 20 % (standard grid-connected system) and 70 % (off-grid installation) of the total system costs. Accordingly the production of BOS products has become an important sector of the overall PV industry. Particularly with the rapid expansion of the worldwide market for grid-connected PV systems, inverters are currently the focus of the interest.

In Europe the large inverter companies are located in Germany, Spain, Austria, Switzerland, Denmark and Italy, with the most notable expansion being the Spanish inverter manufacturers following the massive development of PV in their country during 2008. Outside Europe activities in this field are reported from Japan, the US, Canada and Korea. In addition to the well known PV inverter producers, a number of other established electronics companies are now

increasingly recognizing PV as a promising business opportunity and have either started developing new products or entered joint ventures with PV inverter manufacturers.

Today most of the products are dedicated to the residential PV market, with typical rated capacities from 1 kW to 10 kW and single (Europe) or split phase (America, Japan) grid-connection. In recent years, a considerable increase of average inverter capacities has been observed. For larger systems, typical sizes are 10 kW, 30 kW and 100 kW, which are usually installed in a 3-phase configuration. With the increasing number of MW scale systems being installed in countries such as Spain, Italy, the US and Germany, larger inverters have also been developed with rated capacities up to 2 MW.

In terms of prices, increased production and new market players led to ongoing price reduction of the products. Prices reported for 2008 range from 0,2 EUR/W for large inverters up to 0,5 EUR/W for smaller units.

Tracking systems have recently become more attractive, particularly for PV applications in countries with a high share of direct irradiation and attractive market incentives as in Spain.

In addition to basic BOS components, the production of specialized components, such as PV connectors, DC switchgear, monitoring systems is increasingly becoming an important business for a number of large electric equipment manufacturers.

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.

Table 6 – Indicative installed system prices in selected countries in 2008

Country	Off-grid (EUR or USD per W)				Grid-connected (EUR or USD per W)			
	<1 kW		>1 kW		<10 kW		>10 kW	
	EUR	USD	EUR	USD	EUR	USD	EUR	USD
AUS	10,2–17	15–25	8,5–12,4	12,5–18,3	5,1–7,3	7,5–10,8	3,9–5,6	5,8–8,3
AUT	6–15	8,8–22,1	6–15	8,8–22,1	4,8–5,8	7,1–8,5	4,8–5,5	7,1–8,1
CAN	9,5	14			3,8–4,4	5,6–6,5	3,8–5,1	5,6–7,5
CHE	14,1	20,8	10,5	15,5	6,0–6,4	8,8 – 9,4	5,2–5,4	7,6 – 7,9
DEU					3,9–4,5	5,7–6,6	3,7	5,4
DNK	9,3–12,0	13,7–17,6	20,0–26,7	29,4–39,2	4,7–11,4	6,9–16,7	6,7–13,3	9,8–19,6
ESP	11,4–14,4	16,8–21,2	9,7–11,4	14,3–16,8	7–7,5	10,3–11,0	5,7–6	8,4–8,8
FRA					7–8,3	10,3–12,2	5,1–6	7,5–8,8
GBR	6,2–9,2	9,1–13,6	5,0–9,4	7,3–13,8	4,2–12,6	6,2–18,5	5,0–9,9	7,3–14,5
ISR	6,1	9,0	6,8	10,0	4,1–5,1	6,0 – 7,5		
ITA	10–13	14,7–19,1			5,5–6,5	8,1–9,6	4,2–5,5	6,2–8,1
JPN					4,7	6,9	3,5	5,2
KOR					4,1–5,7	6,1 – 8,4	5,7	8,4
MEX	11,6	17,0	10,0	14,7	8,4	12,4	5,8	8,5
MYS					4,9	7,2	4,9	7,2
NOR	15,0–21,7	22,1–31,9			10,8–14,4	15,9–21,2		
PRT			8–10	11,8–14,7	5–6	7,4–8,8	4,2	6,2
SWE	9,2	13,6			9,9	14,5	6,9	10,2
TUR	8–9	11,8–13,2	6–8	8,8–11,8	4,5	6,6	4	5,9
USA	4,8–6,1	7–9	5,4–6,8	8–10	4,8–6,1	7–9	4,4	6,5

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. Excludes VAT and sales taxes. More expensive grid-connected system prices are often associated with roof integrated slates or tiles or one-off building integrated designs or single projects, and figures can also relate to a single project.

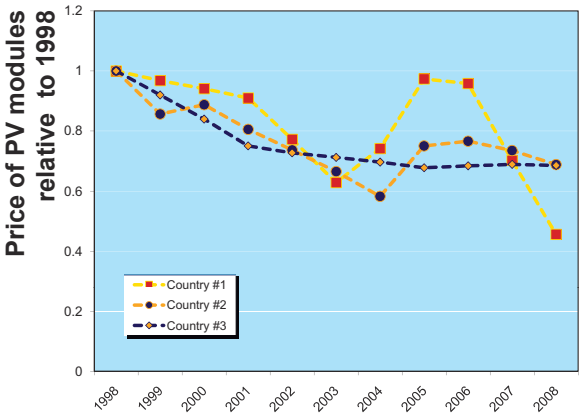

Figure 9 – Evolution of price of PV modules in selected reporting countries accounting for inflation effects – Years 1998–2008 (Normalized to 1998)

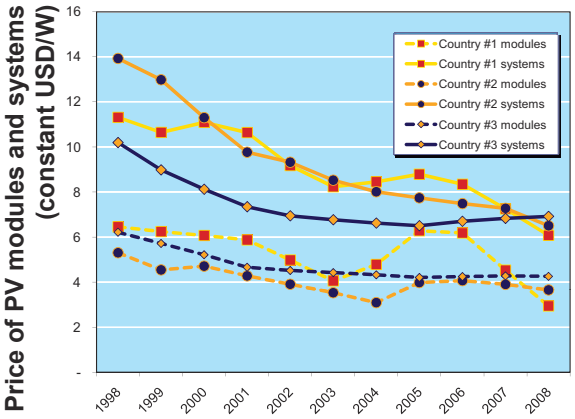

Figure 10 – Evolution of price of PV modules and small-scale systems in selected reporting countries accounting for inflation effects – Years 1998–2008

On average, system prices for the lowest price off-grid applications are roughly double those for the lowest price grid-connected applications. This is attributed to the fact that off-grid systems require storage batteries and associated equipment.

In 2008 the lowest system prices in the off-grid sector, irrespective of the type of application, typically ranged from about 9 USD/W to 15 USD/W. The large range of reported prices in Table 6 is a function of country and project specific factors. The average of these particular system prices is slightly higher than 12 USD/W, about 5 % less than the corresponding prices reported in 2005, 2006 and 2007.

The lowest achievable installed price of grid-connected systems in 2008 also varied between countries as shown in Table 6. The average price of these systems was 6,9 USD/W, much the same as the corresponding prices in 2006 and 2007, and about 5 % higher than the 2004 and 2005 prices. Prices lower than 6 USD/W were reported but typically prices were in the range 6,2 USD/W to 7,6 USD/W.

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.
On average, the cost of the PV modules in 2008 (shown in Table 7) accounts for 58 % of the lowest achievable prices that have been reported for grid-connected systems. In 2008 the average price of modules in the reporting countries was about

Table 7 – Indicative module prices (national currency, EUR and USD per watt) in selected reporting countries

Country	Currency	2008		
		national currency	EUR	USD
AUS	AUD	5,0–8,0	2,9–4,6	4,2–6,7
AUT	EUR	3,0–3,5	3,0–3,5	4,4–5,1
CAN	CAD	3,7–8,0	2,4–5,1	3,5–7,5
CHE	CHF	4,6–4,8	2,9–3,0	4,3–4,4
DEU	EUR	2,0–4,3	2,0–4,3	2,9–6,3
DNK	DKK	30–50	4,0–6,7	5,9–9,8
ESP	EUR	2,3–3,5	2,3–3,5	3,4–5,1
FRA	EUR	3,2	3,2	4,7
GBR	GBP	2,6–3,2	3,2–3,9	4,7–5,8
ISR	NIS	11,8–15,6	2,2–2,9	3,3–4,3
ITA	EUR	2,2–3,3	2,2–3,3	3,2–4,9
JPN	JPY	440	2,9	4,3
KOR	KRW	3 020–3 260	1,8–2,0	2,7–3,0
MEX	MXP	52–78	3,2–4,8	4,7–7,0
MYS			3,1	4,5
PRT	EUR	2,5–3,0	2,5–3,0	3,7–4,4
SWE	SEK	25,5–61,0	2,7–6,3	3,9–9,2
TUR	TRY	6,3–7,4	2,9–3,4	4,3–5,0
USA	USD	3,7	2,5	3,7

Notes: Current prices. Excludes VAT and sales taxes. ISO currency codes are outlined in Table 14.
Single figures generally refer to 'typical' module prices; where there is a 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 survey reports.

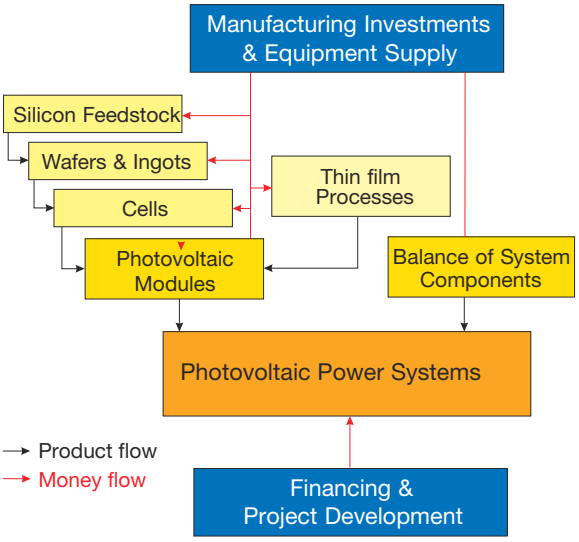

Figure 11 – Photovoltaic (PV) industry supply chain

Table 8 – Estimates of PV labour places in selected reporting countries

Country	Research, development, manufacturing and deployment labour places
AUS	3 800
AUT	1 750
CAN	2 090
CHE	~ 6 500
DEU	> 48 000
DNK	~ 275
ESP	12 200
FRA	~ 4 000
GBR	1 333
ITA	5 700
JPN	~ 18 050
KOR	4 000
MYS	1 270
NOR	1 485
SWE	480
TUR	~ 125

4,0 USD/W, a decrease of 9 % compared to the corresponding figure for 2007. Two thirds of the reporting countries recorded lower module prices than in 2007. Whereas two countries reported module prices less than 3 USD/W, more than 50 % of the lowest achievable prices fell within the range of 3,3 USD/W to 4,4 USD/W. Figure 9 shows the evolution of normalized prices for PV modules, accounting for inflation effects, in selected key markets. Figure 10 shows the trends in actual prices of modules and systems, accounting for inflation effects, in selected key markets.

2.5 *Economic benefits*

The PV industry supply chain provides many opportunities for economic activity, from feedstock production through to system deployment, as well as other supporting activities (Figure 11). This is highlighted by the variety of business models across the IEA PVPS countries. Business value calculations can be found in each national survey report.

Significant value of business has been reported by countries with healthy domestic PV market growth and/or large export of production from somewhere along the PV industry supply chain. Export activities played an important role in many countries in 2008 – for example, manufacturing equipment from Switzerland, silicon feedstock from the US, wafers and ingots from Norway and the UK respectively, PV cells from Australia, Japan, Malaysia and the US, and PV modules from Austria, Canada, the UK, Japan and Sweden. The total value of business in 2008 amongst the IEA PVPS countries approached 40 billion USD.

In parallel with the business value of PV production and markets, the economic value in the IEA PVPS countries can be characterized by the total direct employment (Table 8) of about 111 000 persons across research, manufacturing, development and installation – an increase of about 10 % compared to the 2007 figure which, in turn, had increased by 40 % over 2006. Manufacturing companies worldwide have continued to benefit from the continuing strong level of demand within Germany, the surge in the Spanish market and also the strong market growth in a handful of countries, particularly Italy, Korea, Portugal and the US. The other side of the employment story that has been alluded to in some reports but requires further analysis is firstly, the notion of opportunity cost, i.e. that the indirectly publicly-funded employment in the renewables sector may come at the expense of other publicly-funded jobs (health, education and so on), and secondly, the impact that the collapse of individual PV markets may have on existing jobs.

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, all govern the rate of deployment of PV systems.

3.1 Initiatives supporting photovoltaic power systems

An outline of the range of PV support mechanisms in place in the IEA PVPS countries during 2008 can be found in Table 9. Specific details about many of these measures can be found in section 1.3 of this report and further details are available in the relevant national survey reports. A brief outline of the measures is given the following box.

2008 clearly reinforced the notion that the feed-in tariff (FiT) approach is the prime mechanism for promoting strong growth in grid-connected PV applications. As can be seen in Table 9, the countries not currently employing some form of FiT are in the minority (and, in some cases, have a form of FiT under consideration).

However, the adoption of a FiT scheme continues to generate considerable discussion regarding its implementation. These issues in particular are being tested in PV markets worldwide: payment for all PV electricity generated or only the portion exported to the grid, how to manage take-up rates without using a counter-productive 'cap' approach, how to best reward different types of PV plants and how to manage a transition to grid parity (discussed below). The country descriptions contained in section 1.3 of this report provide an overview of a number of FiT approaches operating in 2008 in different countries – from those that drive investments in large-scale (multi-MW) plants, to those that favour smaller-scale building-integrated applications, and to combinations of both approaches.

During 2008, under feed-in tariff schemes in the IEA PVPS countries, payments of over 7 billion USD were made for PV electricity (over 30 times the total budget

Enhanced feed-in tariff	an explicit monetary reward is provided for producing PV electricity; paid (usually by the electricity utility) at a rate per kWh somewhat higher than the retail electricity rates being paid by the customer
Capital subsidies	direct financial subsidies aimed at tackling the up-front cost barrier, either for specific equipment or total installed PV system cost
Green electricity schemes	allows customers to purchase green electricity based on renewable energy from the electricity utility, usually at a premium price
PV-specific green electricity schemes	allows customers to purchase green electricity based on PV electricity from the electricity utility, usually at a premium price
Renewable portfolio standards (RPS)	a mandated requirement that the electricity utility (often the electricity retailer) source a portion of their electricity supplies from renewable energies (usually characterized by a broad, least-cost approach favouring hydro, wind and biomass)
PV requirement in RPS	a mandated requirement that a portion of the RPS be met by PV electricity supplies (often called a set-aside)
Investment funds for PV	share offerings in private PV investment funds plus other schemes that focus on wealth creation and business success using PV as a vehicle to achieve these ends
Income tax credits	allows some or all expenses associated with PV installation to be deducted from taxable income streams
Net metering	in effect the system owner receives retail value for any excess electricity fed into the grid, as recorded by a bi-directional electricity meter and netted over the billing period
Net billing	the electricity taken from the grid and the electricity fed into the grid are tracked separately, and the electricity fed into the grid is valued at a given price
Commercial bank activities	includes activities such as preferential home mortgage terms for houses including PV systems and preferential green loans for the installation of PV systems
Electricity utility activities	includes 'green power' schemes allowing customers to purchase green electricity, large-scale utility PV plants, various PV ownership and financing options with select customers and PV electricity power purchase models
Sustainable building requirements	includes requirements on new building developments (residential and commercial) and also in some cases on properties for sale, where the PV may be included as one option for reducing the building's energy foot print or may be specifically mandated as an inclusion in the building development

for PV market stimulation in the IEA PVPS countries about a decade ago). The extent to which some countries' FiT schemes can influence the evolution of world prices for PV modules is unknown, but this possibility has become less significant as an increasing number of countries' markets rapidly develop and global industry competition increases.

A comprehensive analysis of initiatives promoting PV systems can be found in a recently published IEA PVPS Task 10 report, Promotional Drivers for PV. The report makes the point that the success or otherwise of PV deployment programmes depends on many variables and a number of interesting conclusions can be drawn from the work. Some of the more pertinent are as follows:

- worldwide, imperfect markets for grid-connected PV still persist
- promotional policies should be designed primarily to reduce installation costs (and, by implication, industry policies should be developed to address equipment production costs)
- the Japanese Residential PV System Dissemination Programme has proven to be the most efficient in terms of decreasing system costs, due mainly to its continuity and the subsequent boosting of industry confidence
- although capital subsidies (rebates on investments) have been criticized for not promoting optimal performance of the PV system over its lifetime, other measures – monitoring programmes, supervision or subsidies dependent on the system efficiency – do create a positive effect. It is also worth noting that capital subsidies can effectively tackle the up-front cost barrier, which is often the most significant hurdle facing PV deployment even with a FiT, and can be used in both the grid-connected and off-grid markets

Table 9 – PV support mechanisms & indicative retail electricity prices reported by selected reporting countries

	AUS	AUT	CAN	CHE	DNK	DEU	ESP	FRA	GBR	ISR	ITA	JPN	KOR	MEX	MYS	NLD	NOR	PRT	SWE	USA
Enhanced feed–in tariffs	•	•	•	•		•	•	•		•	•		•			•		•		•
Direct capital subsidies	•	•		•		•		•	•		•	•	•		•				•	•
Green electricity schemes	•	•	•	•		•	•		•		•	•								•
PV-specific green electricity schemes	•	•		•																•
Renewable portfolio standards (RPS)	•								•			•							•	•
PV requirement in RPS																				•
Investment funds for PV			•			•	•													•
Tax credits			•	•				•	•			•			•			•		•
Net metering	•	•	•	•	•				•		•			•	•					•
Net billing			•	•		•			•	•		•			•					•
Commercial bank activities	•					•			•			•				•				•
Electricity utility activities	•		•	•	•	•	•		•	•		•								•
Sustainable building requirements	•		•	•		•	•		•				•					•		•
Indicative household retail electricity price USD cents (1.)	10 – 14,2	26,5	7		30,7	32,4	13,7		23,8	15,3	25		15,3 – 22,6	up to 36	8,7		12,4 – 15,9		21,2 – 25,8	10,2

Notes:
1. Typical residential kWh price expressed in USD cents (1 USD/100), including all taxes but not including variations due to time of use, total electricity consumption or any fixed rates

- the convergence of system cost and the consumer's willingness to pay is an important but often unexplored feature of the grid-connected PV market (however, the bidding mechanism used in Malaysia's SURIA 1000 Programme does address this aspect). Willingness to pay directly relates to the particular added values of PV (beyond energy) that are significant for each individual, and these should be quantified. Different added values assume differing levels of significance according to the various groups of customers – residential customers, businesses, architects, electricity utilities and governments.
- well designed feed-in tariffs can promote larger-scale projects, higher investment volumes and faster results
- often some of the clear advantages of PV deployment – such as decentralized power generation and high levels of building integration – are not captured by deployment programmes in many countries
- private and voluntary initiatives are not sufficient to develop a sustainable local market but can be useful in the short term if public awareness and interest are high
- although there is obvious merit in identifying and evaluating subsidies that have a least cost for the public, a more robust policy analysis also takes into account such things as labour places and wealth creation.

Table 10 – Characteristics of some key support measures

	Enhanced feed-in tariffs	**Direct capital subsidies**	**Green electricity schemes**	**Renewable portfolio standards**	**Tax credits**	**Sustainable building requirements**
Target audience	Grid-connected PV customers with business cash flow requirements e.g. housing developers, investors, commercial entities.	PV customers with limited access to capital e.g. households, small businesses, public organizations.	Residential and commercial electricity customers.	Liable parties, typically the electricity retailing businesses.	Any entity with a tax liability, such as salary earners and businesses. However, may not be relevant for many prime candidates for PV.	New building developments (residential and commercial); also properties for sale.
Countries reporting use of this support measure, or similar	Australia, Austria, Canada, Switzerland, Germany, Spain, France, Israel, Italy, Korea, the Netherlands, Portugal, USA.	Australia, Austria, Switzerland, Germany, France, UK, Italy, Japan, Korea, Malaysia, Sweden, USA.	Australia, Austria, Canada, Switzerland, Germany, Spain, UK, Italy, Japan, USA.	Australia, UK, Japan, Sweden, USA.	Canada, Switzerland, France, UK, Japan, Malaysia, Portugal, USA.	Australia, Canada, Switzerland, Germany, UK, Spain, Korea, Portugal, 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.	Administered by the existing taxation bodies.	Typically administered by the local building consent authority.
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.	Government involvement in selective, customer-driven, electricity business commercial activities raises some interesting questions. However, 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.	Same benefits as the direct capital subsidies but without some of the negatives.	Appeal largely depends upon the degree to which property prices are impacted and the cultural acceptance of prescriptive approaches.
	There are varying political perceptions regarding the use of public funds or funds generated by the electricity industry.					

Table 10 provides a broad overview of some of the key PV support measures. In practice, public support can involve a combination of measures. Across the countries represented there is no correlation between number of measures employed and capacity of PV installed. However, on the one hand, while fewer measures are likely to incur a lower administrative burden, on the other hand more measures may mean greater flexibility to deal with unforeseen circumstances. Funding issues are significant and funding continuity is critical to the success of any mechanism.

Any measure should be evaluated against a number of criteria: While outcomes have been achieved elsewhere are the local barriers to be addressed the same as those tackled in other markets? Is the local electricity industry structure compatible with the approach? Will the scheme be flexible enough to survive political change? Can the scheme alone transform the market? How costly is the administrative burden compared to that of other approaches? Is the free-rider effect minimized? And, what are the overall socio-economic-environmental impacts of the measure?

3.2 Indirect policy issues and their effect on the PV market

Two issues are particularly relevant to the market for PV – climate change policy deliberations and electricity utility developments.

A number of governments are implementing the regulatory approach commonly referred to as the 'renewable portfolio standard' (RPS) to increase renewable energy deployment in their countries, and this approach is likely to be adopted in an increasing number of countries. However, in its simplest form, the RPS is unlikely to have a positive impact on PV deployment as the general requirement for renewable energy may simply encourage the lowest direct cost renewable energy options (and not PV) for consideration. In the US a number of PV-specific regulatory approaches, such as PV set-asides, have been developed (details about these programmes can be found at www.dsireusa.org). Other countries (for example Australia and Japan) are refining their RPS approaches in ways that will benefit PV. One method is to allow PV electricity to earn multiple certificates (the currency of the RPS) compared to other renewable technologies, with the multiplier able to be varied over time to reflect the increasing cost-competitiveness of PV electricity.

In addition, sustainable building regulations are an emerging force in many countries (Australia, Canada, Switzerland, Germany, UK, Spain, Korea, Portugal and the US). These include requirements on new building developments (residential and commercial) and also in some cases on properties for sale. The implications for PV deployment may be modest where, for example, PV is included in a suite of options for reducing the building's energy foot print, or dramatic as is the case in Spain and Italy where PV is specifically mandated as an inclusion in the building development.

Grid parity is the term that is used to describe the point in time when the cost of electricity from PV systems matches the price paid by consumers for retail electricity. It is regarded as an important target for the PV industry and various commentators anticipate that it will occur within five to ten years in a number of countries. Of course the variations in retail electricity prices (Table 9) between countries are an important consideration - grid parity will approach at different times in different countries. It is thought that grid parity will lead to a new, strong growth in consumer demand for PV within a truly sustainable market no longer requiring government support. Some questions remain about the ability of electricity networks to accept large amounts of PV electricity and this has driven the development of a number of solar cities or towns (e.g. Pal Town in Ota City, Japan) and various recent R&D programmes (section 1.4) to investigate network issues.

The role of the electricity utilities is likely to become much more important for PV over time – beyond concerns about the ability of electricity networks to accept large amounts of PV electricity. Worldwide we are seeing electricity utilities, driven by both government mandates and business opportunities, investing in very large-scale PV plants or asking how they can benefit from meeting their customers' interest in PV plants or PV electricity. Regarding the final point, a number of approaches have emerged, for example in Denmark, the US and Australia. The Swiss solar stock exchanges, in which PV power is produced and sold to individuals and institutions interested in purchasing clean electricity, have proved to be a mainstay in the promotion of PV in Switzerland. Japanese electricity utilities introduced the 'Green Power Fund' based on contributions from supporting customers. At the electricity customer / PV owner level, the individual's financial interest (whether the PV electricity is for own-consumption or export to the electricity network) is going to be underpinned by smart metering and an equally smart rate structure – both of which are now attracting increasing public attention worldwide. In the US, in particular, electricity utilities are already actively exploring a range of business models for their involvement with PV – from large-scale utility plants to ownership and financing options with select customers to various power purchase models.

2.25 kW System integrated in the facade on the municipal school Slotsskolen, Horsens, Denmark

As the PV market matures and opportunities for business are identified, various non-utility commercial initiatives have emerged (for example in Australia, Germany, the UK, Japan, the Netherlands and the US). 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.

The vitally important role that PV can play in the developing countries needs to be highlighted, with one third of the world's population still not having access to grid electricity. PV offers the ability, sometimes uniquely, to provide electricity to populations remote from electricity grids and also to enhance the quality of existing electricity supplies. Although not directly mentioned in the UN Millennium Development Goals, access to electricity is a recognized prerequisite for meeting these goals and, with a steadily decreasing cost of PV technology, it is anticipated that PV should play an increasing role in meeting the electricity needs in developing countries.

3.3 Standards and codes

Established in 1981, 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. As of end 2008, 74 IEC International Standards and Technical Specifications (including versions in different languages) had been published covering a comprehensive range of issues. Currently 29 countries are active participants in TC 82 and a further 13 have observer status, with four more countries joining in 2008.

The 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 treated within the framework of the IECEE (Worldwide System for Conformity Testing and Certification of Electrical Equipment).

TC 82 has been very active during 2008 and has published the following new or revised IEC standards or Technical Specifications (TS)

- IEC 60904 Photovoltaic devices
  - Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data
  - Part 7: Computation of the spectral mismatch correction for measurements of photovoltaic devices
- IEC 61646 (2008-05) Ed. 2.0 Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval
- IEC 62116 (2008-09) Ed. 1.0 Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters
- IEC/TS 62257 Recommendations for small renewable energy and hybrid systems for rural electrification
  - Part 7: Generators
  - Part 7-3: Generator set – Selection of generator sets for rural electrification systems
  - Part 9-1: Micropower systems
  - Part 9-6: Integrated system – Selection of Photovoltaic Individual Electrification Systems (PV-IES)

Continuing the activities from the previous year, revisions to the IEC 60904-X series, which define fundamental requirements such as measurement principles for photovoltaic devices, have been on top of TC 82's agenda. Further important work items currently on top of TC 82's list include among others Safety of PV power converters, which will be covered by the IEC 62109-X series, and the completion of the series of Technical Specifications (TS) on Rural Electrification.

At the European level the CLC/TC 82 of the European Committee for Electrotechnical Standardization (CENELEC) closely cooperates with its counterpart, the IEC TC 82 as well as the national committees. In areas where there is special European concern, CLC/TC 82 is also developing its own standards. In 2008, the European Standard "EN 50521:2008 Connectors for photovoltaic systems – Safety requirements and tests" has been published. Further priority projects on CLC/TC 82's agenda deal with specifications for solar wafers, data sheet information and the performance of grid-connected PV inverters.

In the US standardization focuses on safety and interconnection issues of PV systems. Technology acceptance activities of the DOE PV programme included the creation of the Solar America Board of Codes and Standards (SolarABCs), which is designed to improve the development of codes and standards that facilitate the installation of safe, high-quality PV systems.

Underwriters Laboratories is working to conform the UL1741, 'Standard for Static Inverters and Charge Controllers for Use In Photovoltaic Power Systems', to IEC standards. Coordination with both the NEC and IEEE interconnect guidelines will remain a valuable activity for finalizing the revised UL1741 standard that now integrates with IEEE1547.1 for anti-islanding and other performance requirements. Personnel from Sandia continue to update a draft test protocol for performance certification of inverters for PV applications to include assessment of maximum-power-point tracking and array utilization. In addition, U.S. representatives also actively participate in the IEC TC 82.

In Japan, the Japanese Standards Association and the Japan Electrical Safety and Environment Technology Laboratories (JET) are very active in the field of PV standardization. Japanese PV standards are widely consistent with the corresponding IEC documents; however some of them reflect the unique circumstances of Japan. In addition to the current standards which cover mostly component issues, vigorous efforts are currently made to establish standards for the entire PV system.

Following the enormous growth of grid-connected PV in a number of PVPS countries, most notably in the two main markets in 2008 – Spain and Germany, full integration of PV systems into grid operation is now becoming more and more critical. This is clearly reflected by. for example, the new German Medium Voltage grid connection guidelines adopted in 2008. This document requires, for the first time, larger PV installations to actively support the grid by providing ancillary services. In the mid-term, the new requirements are expected to enable a considerably increased PV generation capacity to be connected to the distribution systems.

4 Summary of trends

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

- About 5,56 GW of PV capacity were installed in the IEA PVPS countries during 2008 (an increase of about 150 % over the previous year) which brought the total installed capacity to 13,4 GW. By far the greatest proportion (75 %) was installed in Spain and Germany alone. If Italy, the US, Korea and Japan are also included, then over 96 % of PV installations in 2008 occurred in six countries. Spain's cumulative installed capacity increased almost five-fold. Growth of the annual market was evident in a number of countries. The Korean annual PV market increased six-fold. The Spanish annual market increased almost five-fold, as did the Italian market. The French annual PV market more than tripled as did the Portuguese market.

- Grid-connected applications dominated in the reporting countries (about 99 % of the 2008 market) but the largely unsubsidized off-grid markets continued to grow worldwide, albeit less vigorously than the publicly funded grid-connected PV markets. In 2008 grid-connected centralized applications grew to comprise 35 % of the grid-connected cumulative installed capacity. This reflects the market for utility-scale PV power systems being developed in a number of countries

- The 2008 total expenditure on R&D of about 425 million USD (290 million EUR) represents an increase of almost 30 % over the 2007 amount. During the year, under feed-in tariff schemes in the IEA PVPS countries, payments of over 7 billion USD (4,8 billion EUR) were made for PV electricity.

- In 2008 solar photovoltaic grade silicon feedstock supply remained dominated by the three major producing countries: Germany, the US and Japan. A feature of interest in 2008 was the dramatic (five-fold) increase in production in the US, with four active manufacturers, exporting about 85 % of production. The key current production countries plus other IEA PVPS countries and other newcomers have flagged future developments. European (particularly Norway, Germany and the UK) and Japanese companies feature most prominently in the ingot and wafer section of the PV industry value chain.

- The total PV cell production volume for 2008 in the IEA PVPS countries was reported to be at least 3 740 MW, up from 2 400 MW in 2007, an increase of 56 %. The largest increase in production took place in Germany (which came close to doubling its production to about 1 500 MW) while Japan's production increased by 33 %.

- Germany replaced Japan as the leading producer of photovoltaic cells during 2008. Production of cells and modules in this country accounted for

Table 11 – Cumulative installed PV power and annual percentage increase

Year	Off-grid		Grid-connected		Total	
	Cumulative (MW)	Increase (%)	Cumulative (MW)	Increase (%)	Cumulative (MW)	Increase (%)
1992	78		27		105	
1993	94	21	36	33	130	24
1994	112	19	46	28	158	22
1995	132	18	60	30	192	22
1996	158	19	79	32	237	23
1997	187	19	118	49	305	29
1998	216	15	170	44	386	27
1999	244	13	266	56	510	32
2000	277	14	439	65	716	40
2001	319	15	656	49	975	36
2002	354	11	964	47	1 318	35
2003	410	16	1 400	45	1 810	37
2004	450	10	2 385	70	2 835	57
2005	485	8	3 703	55	4 188	48
2006	535	10	5 092	38	5 627	34
2007	663	24	7 203	41	7 866	40
2008	741	12	12 684	76	13 425	71

40 % and 22 % respectively of the IEA PVPS countries' production, with Japan in second place with 30 % and 19 % for shares of cell and module production respectively. In the United States, the third largest PV cell producing country, production increased by 62 % from 2007. Spain's module production occupies the third position during 2008. US output of thin film technologies increased by over 50%, while Germany's thin film production tripled – between them these two countries represented two thirds of world thin film production in 2008.

- In 2008 wafer-based crystalline silicon technologies maintained their dominance, accounting for about 78 % of the market for PV modules in the IEA PVPS countries. However, this percentage has slipped a further nine percentage points from 2007, following a loss of four percentage points the previous year. This is due to thin film technologies steadily increasing their share of an expanding market. Total module production increased by almost 50 % from 2007, following similar growth the previous year.

- Countries not part of the IEA PVPS reporting process now possibly account for close to 50 % of world PV cell production. In 2008, installed market capacity in the IEA PVPS countries exceeded module production by close to 40 %.

- Some common themes identified in previous years still seem to apply to the PV industry in 2008, to a varying degree. Cell supply shortages still created difficult circumstances for some module producers but this appears to have eased (at least in some countries). Foreign product and price offers are increasingly impacting domestic markets. Access to a booming foreign market provides an ongoing lifeline for the industries in some countries where the domestic market has slowed appreciably. Large and successful players in the PV supply chain are, by necessity, becoming increasingly multinational in their operations.

- On average, the cost of the PV modules in 2008 accounts for 58 % of the lowest achievable prices that have been reported for grid-connected systems. In 2008 the average price of modules in the reporting countries was about 4,0 USD/W, a decrease of 9 % compared to the corresponding figure for 2007.

- The average lowest achievable installed price of grid-connected systems in 2008 was 6,9 USD/W, much the same as the corresponding prices in 2006 and 2007, and about 5 % higher than the 2004 and 2005 prices. Prices lower than 6 USD/W were reported but typically prices were in the range 6,2 USD/W to 7,6 USD/W. On average, system prices for the lowest price off-grid applications are double those for the lowest price grid-connected applications.

- The total value of business in 2008 amongst the IEA PVPS reporting countries approached 40 billion USD (27 billion EUR). In parallel with the business value of PV production and markets, the economic value in the IEA PVPS countries can be characterized by the total direct employment of about 111 000 persons across PV research, manufacturing, development and installation – an increase of about 10 % compared to the 2007 figure.

- 2008 clearly reinforced the notion that the feed-in tariff (FiT) approach is currently the prime mechanism for promoting strong growth in grid-connected PV applications. Across the IEA PVPS countries a number of other key PV support measures also exist and have demonstrated success. Two broader issues are particularly relevant to the future market for grid-connected PV – climate change policy deliberations and the role of electricity utilities.

Table 12 – Installed PV power and module production in the IEA PVPS reporting countries

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Power installed during year in IEA PVPS reporting countries (MW)	26	26	34	45	69	80	124	206	259	344
Module production during year in IEA PVPS reporting countries (MW)	52		56		100	126	169	238	319	482

	2003	2004	2005	2006	2007	2008
Power installed during year in IEA PVPS reporting countries (MW)	491	1 023	1 322	1 430	2 257	5 559
Module production during year in IEA PVPS reporting countries (MW)	667	1 160	1 532	1 668	2 690 *(estimate)*	4 000 *(estimate)*

Table 13 – IEA PVPS Task 1 participating countries and national survey report authors

Australia	AUS	Muriel Watt, IT Power Australia, for the Australian PV Association
Austria	AUT	Roland Bründlinger, N Glück, Arsenal Research, and Hubert Fechner, University of Applied Science Technikum Wien
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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 and Greg Watt.

Acknowledgements

The report authors gratefully acknowledge the editorial assistance received from a number of their Task 1 colleagues.

The non-PVPS country reports are drawn predominately from information provided by the Abu Dhabi Future Energy Company, Ashden Trust, EPIA, Ministry of New and Renewable Energy (India), Photon International, PV News, and Photovoltaics in the European Union New Member States (PV-NMS.NET). These sources and the assistance of Naeem Datardina and Dwipen Boruah are gratefully acknowledged.

Exchange rates

Table 14 lists the reporting countries, corresponding currency codes, and the exchange rates used to convert national currencies. Exchange rates represent the 2008 annual average of daily rates (source: OECD Main Economic Indicators July 2009).

Table 14 – Currency exchange rates

Country	Currency and code	Exchange rate (1 USD =)	Country	Currency and code	Exchange rate (1 USD =)
Australia	dollar (AUD)	1,20	Norway	krone (NOK)	5,65
Canada	dollar (CAD)	1,07	Sweden	krona (SEK)	6,60
Denmark	krone (DKK)	5,10	Switzerland	franc (CHF)	1,08
Israel	NIS	3,59	United Kingdom	pound (GBP)	0,55
Japan	yen (JPY)	103,39	United States	dollar (USD)	1
Korea	won (KRW)	1 100,86	Austria, France, Germany, Italy, the Netherlands, Portugal, Spain	euro (EUR)	0,68
Mexico	peso (MXP)	11,15			
Turkey	Turkish lira (TRY)	1,48			

Photovoltaic (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 device, typically available in 12,5 cm, 15 cm and up to 20 cm square sizes. In general, cells can be classified as either wafer-based *crystalline (single crystal or multicrystalline)* or *thin film*. Currently wafer-based crystalline silicon technologies account for most of the overall cell production in the IEA PVPS countries.
Single crystal silicon (sc-Si) PV cells are manufactured using a single crystal growth method and have commercial efficiencies between 15 % and 18 %.
Multicrystalline silicon (mc-Si) cells, usually manufactured from a melting and solidification process, are becoming increasingly popular as they are less expensive to produce but are marginally less efficient, with an average conversion 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 conversion 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 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 Ed. 2, IEC 61646 Ed. 2.0 and IEC 61730 International Standards.

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'. Single or two-axis ***tracking systems*** have recently become more and more attractive, particularly for PV applications in countries with a high share of direct irradiation. By using such systems, the energy yield can be typically increased by about 30 % compared with non-tracking systems.

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 95 %, with peak efficiencies up to 98 %. 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 very limited 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. NiCad, 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 photovoltaic technology and applications can be found on the IEA PVPS website at www.iea-pvps.org.

Report IEA-PVPS T1-18:2009 Printed in Switzerland ***www.suterdruck.ch***