IEA INTERNATIONAL ENERGY AGENCY

TRENDS IN PHOTOVOLTAIC APPLICATIONS

Survey report of selected IEA countries between 1992 and 2010

PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

Report IEA-PVPS T1-20:2011

TRENDS IN PHOTOVOLTAIC APPLICATIONS

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Foreword

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the 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, Turkey, the Solar Electric Power Association and China are recent participants.

I am pleased to present the 16th edition of the IEA PVPS international survey report on Trends in Photovoltaic Applications. 2010 has been another year of tremendous further market growth, massive cost reduction and signs of industry and market consolidation. In total, about 14,2 GW of PV capacity were installed in the IEA PVPS countries during 2010 (2008: 6,2 GW), thus more than doubling the installed capacity of the year before; this raised the total installed capacity in IEA PVPS countries to 35 GW with another estimated 4 GW of capacity installed in further countries. By far the greatest proportion (69 %) was installed in Germany and Italy alone. If the US, Japan and France are also included, then over 87 % of PV installations in 2010 occurred in five countries. On the other hand, many countries experienced an annual market increase on the order of two to five-fold. Overall, PV markets thus grow substantially in an increasing number of countries, although at different absolute levels. A trend to a more balanced global market can therefore be observed. Grid-connected applications dominated in the reporting countries (about 99 % of the 2010 market) but the largely unsubsidized off-grid markets continued to grow worldwide, albeit less vigorously than the grid-connected PV markets. Prices as low as 3,0 USD/W were reported for grid-connected systems in 2010, but typically prices were in the range 4 USD/W to 6 USD/W. The industry supply side analysis of this year's report is strongly influenced by China as the biggest worldwide module producer and now a member of the IEA PVPS Programme. These few highlights are examples of the industry and market analysis that IEA PVPS is undertaking, thereby tracking the very dynamic development of the global PV sector. I am confident that this new edition of Trends in Photovoltaic Applications will again find many interested readers.

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.

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 16th international survey. It provides an overview of PV power systems applications, markets and production in the reporting countries and elsewhere at the end of 2010 and analyzes trends in the implementation of PV power systems between 1992 and 2010.

Lausanne,Switzerland, techn. university, courtesy SOLSTIS SA

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

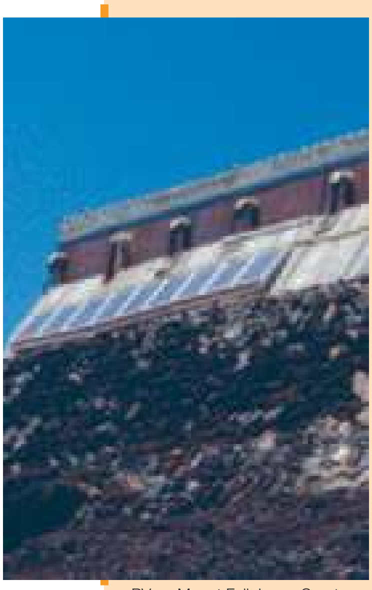
1.1 Applications for photovoltaics

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.

New Monte Rosa Hut SAC, courtesy Peter Dransfeld

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.



PV on Mount Fuji Japan Courtesy Izumi Kaizuka

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.

Roof integrated PV system with frameless CIGS tin film modules, courtesy of Wurth Solar/Germany

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.

Salmdorf, Germany, 1 MW, courtesy BSW-Solar/FirstSolar

1.2 Total photovoltaic power installed

About 14,2 GW of PV capacity were installed in the IEA PVPS countries (now including China) during 2010 – more than double the amount as in the previous year. This brought the cumulative installed capacity to almost 35 GW. By far the greatest proportion (69 %) was installed in Germany and Italy alone. If the US, Japan and France are also included, then over 87 % of PV installations in 2010 occurred in five countries.

If Spain's explosive 2008 PV market and almost total collapse in 2009 are removed from the dataset, the growth rate between the 2008 and 2009 annual markets for the remaining 20 countries was an impressive 84 % – a very healthy number during a period of global economic slowdown. In 2010 this growth rate was echoed with an equally impressive 68 % increase in cumulative installed capacity.

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 1a 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

Table 1 – Reported PV power capacity in participating IEA PVPS countries as of the end of 2010

Country*	Cumulative off-grid PV capacity** (MW)		Cumulative grid-connected PV capacity (MW)		Cumulative installed PV power	Cumulative installed per capita	PV power installed during 2010	Grid-connected PV power installed during 2010 (MW)
	domestic	non-domestic	distributed	centralized	(MW)	(W/Capita)	(MW)	
AUS	44,2	43,6	479,3	3,8	570,9	25,19	383,3	379,5
AUT	3,8		91,7		95,5	11,36	42,9	42,7
CAN	22,9	37,2	37,7	193,3	291,1	8,43	196,6	171,7
CHE	4,2		104,1	2,6	110,9	14,10	37,3	37,1
CHN					800	0,6	500	
DEU	50		17320		17370	212,47	7411	7406
DNK	0,2	0,5	6,4	0	7,1	1,28	2,4	2,3
ESP					3915	84,83	392	389
FRA	29,8		830,3	194,2	1054,3	16,02	719	716
GBR*					69,8	1,07	40,1	
ISR	3,0	0,3	66,6	~	69,9	9,02	45	45
ITA	4	9	1532,6	1956,7	3502,3	57,76	2321	2321
JPN	3,4	95,4	3496,0	23,3	3618,1	28,28	991,0	986,8
KOR	1,0	5,0	131,3	518,3	655,6	13,38	131,2	131,2
MEX	19,1	6,3	4,2	1,0	30,6	0,27	5,6	3,9
MYS	11,0		1,6		12,6	0,46	1,5	0,5
NLD					88	5,27	21	
NOR	8,4	0,5	0,2	0	9,1	1,83	0,4	0,1
PRT	3,1		33,1	94,6	130,8	12,30	28,6	28,5
SWE	4,9	0,8	5,4	0,3	11,4	1,21	2,7	2,1
TUR	1,2	4,2	0,6	0	6,0	0,08	1,0	0,1
USA	440		1727	367	2534	8,13	918,0	887,0
Estimated totals for all IEA PVPS countries (MW)	**980**		**33 973**		**34 953**		**14 192**	**14 098**

Notes:
**The UK has not yet provided information for 2010. Figures estimated from Dept. of Energy and Climate Change information.*
*** Some off-grid capacity, installed since the 1970's, has been de-commissioned in various countries but is difficult to quantify.*
The characteristics of some national markets, particularly the relative effectiveness of grid connection procedures, can cause disparities between capacity physically installed and capacity recorded as operational. ISO country codes are outlined in Table 13.

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	2009	2010
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	187,6	570,9
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	52,6	95,5
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	94,6	291,1
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	73,6	110,9
CHN	~	~	~	~	~	~	~	~	~	~	~	~	~	~	80	100	140	300	800
DEU	3	5	6	8	11	18	23	32	76	186	296	439	1074	1980	2931	4205	6160	9959	17370
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	4,6	7,1
ESP	~	~	1	1	1	1	1	2	2	4	7	12	24	49	148	705	3463	3523	3915
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	335,2	1054,3
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	26,0	69,8
ISR	~	~	~	~	~	~	~	~	~	~	~	~	0,9	1,0	1,3	1,8	3,0	24,5	69,9
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	1181,3	3502,3
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	1132,0	1421,9	1708,5	1918,9	2144,2	2627,2	3618,1
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	524,2	655,6
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	25,0	30,6
MYS	~	~	~	~	~	~	~	~	~	~	~	~	~	~	5,5	7,0	8,8	11,1	12,6
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	56,8	67,5	88
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	8,7	9,1
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	102,2	130,8
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	8,8	11,4
TUR	~	~	~	~	~	~	0,2	0,3	0,4	0,6	0,9	1,3	1,8	2,3	2,8	3,3	4,0	5,0	6,0
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	1168,5	1616	2534
Total	**103**	**127**	**151**	**181**	**219**	**281**	**355**	**471**	**678**	**966**	**1337**	**1818**	**2876**	**4243**	**5882**	**8347**	**14493**	**20758**	**34953**

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 each year as required. The UK has not yet provided information for 2010. Figures estimated from Dept. of Energy and Climate Change information. Some off-grid capacity, installed since the 1970's, has been de-commissioned in various countries but is difficult to quantify.

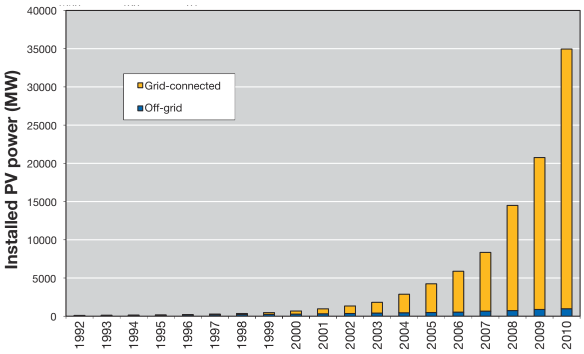


Figure 1a – Cumulative installed PV power in the reporting countriess

reported installed capacity represents a significant and increasing proportion of worldwide PV capacity.

Five countries rank in the GW cumulative installed PV capacity grouping. Germany's cumulative installed capacity grew at 74 % whereas Japan's growth rate approached 38 %. Cumulative installed capacity in the US increased at 57 %. Italy's cumulative installed capacity tripled, as did France's.

Continued dramatic growth of the annual grid-connected PV market worldwide is shown in Table 3a.

Significant growth of the annual market was evident in a number of the largest markets (Table 3b).
In 2010 the size of Germany's annual PV market was largest (by an order of magnitude compared to most other markets), exceeding any other country's annual market by a massive 5 GW, with quite a drop to Italy followed by Japan and the US, then France followed by China. Germany still has the highest level of installed capacity in terms of total capacity (about 17,4 GW) and by far the highest installed capacity per capita (over 212 W/capita).

The Off-grid market

With so much emphasis on the relatively large numbers associated with grid-connected markets, off-grid markets tend to be ignored. This is unfortunate as these applications have the scope to dramatically change the lives of some of the world's most disadvantaged peoples. It is useful to separate information about the growth of this market (figure 1b) as off-grid tends to get lost amongst the explosive growth of PV in total. The market itself is healthy with sustained, solid growth over decades, and not subject to the same sort of political whims and flights of fancy as grid-connected PV. This market is also largely unsupported by public funding. Of the total capacity installed in the IEA PVPS countries during 2010, less than 0,7 % were installed in off-grid projects and these

Table 3a – Estimated annual PV power (MW) installed in all IEA PVPS countries – historical perspective (1995–2010)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Off-grid*	20	26	29	29	28	33	42	35	56	40	35	50	128	78	142	97
Grid-connected	10	12	33	45	88	174	246	336	425	1 018	1 332	1 589	2 337	6 068	6 123	14 098

** Some off-grid capacity, installed since the 1970's, has been de-commissioned in various countries but is difficult to quantify.*

Table 3b – Annual installed photovoltaic power (MW) in top-ten countries by cumulative installed capacity – historical perspective (1995–2010)

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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	79,1	383,3
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	61,9	196,6
CHN	~	~	~	~	~	~	~	~	~	~	~	10	20	40	160	500
DEU	2	3	7	5	9	44	110	110	143	635	906	951	1 274	1 955	3 799	7 411
ESP	~	~	~	~	~	~	2	3	5	11	25	99	557	2 758	60	392
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	155,5	719
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	723,0	2 320,9
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	483,0	991,0
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	166,7	131,2
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	447,5	918,0

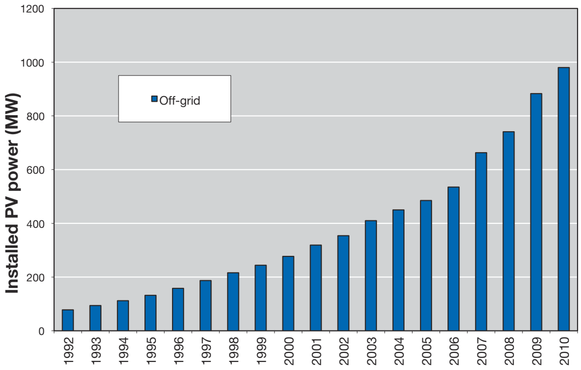


Figure 1b – Cumulative installed off-grid PV power in the reporting countries

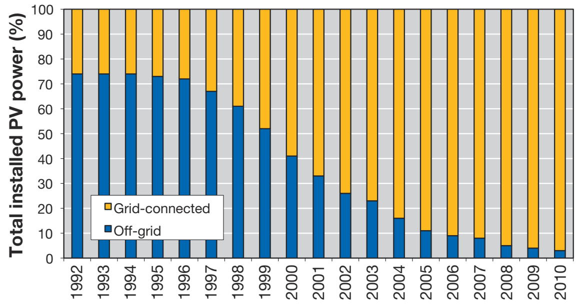


Figure 2 – Percentages of grid-connected and off-grid PV power in the reporting countries

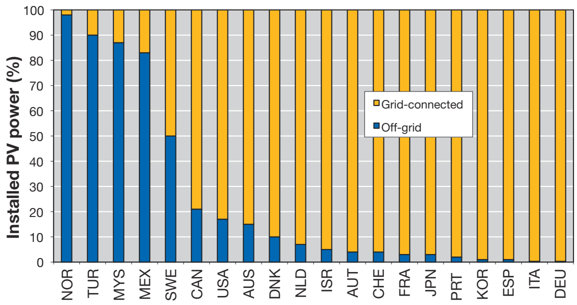


Figure 3a – Installed PV power in the reporting countries by application (%) in 2010

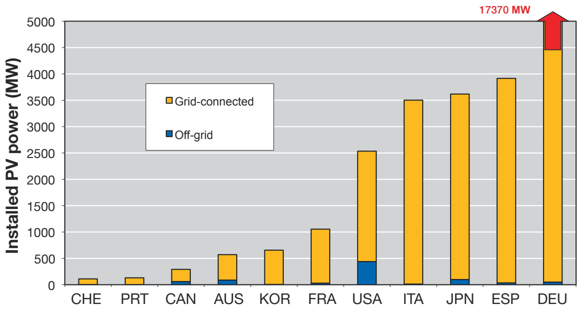


Figure 3b – Installed PV power in selected reporting countries by application (MW) in 2010

now make up about 3 % of the cumulative installed PV capacity of the IEA PVPS countries. Figure 2 shows the dominance now achieved by grid-connected applications in an increasing number of countries. It is interesting to note that it was only a little over one decade ago that the installed capacities of off-grid and grid-connected applications were divided almost equally. Figure 3a illustrates the proportion of various PV applications in the reporting countries. Figure 3b provides a snapshot of the off-grid / grid-connected installed capacities in some of the larger markets.

1.3 PV implementation highlights from selected countries

The information presented in this section reflects the diversity of PV deployment activity in the reporting countries and the various stages of maturity of PV implementation throughout these countries. 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 383 MW of PV were installed in Australia in 2010, an almost fivefold increase on 2009 levels. Of this, 99 % were grid-connected, taking the cumulative grid-connected portion to nearly 85 %, up from 19 % three years previously. The market is dominated by the high uptake of grid-connected distributed systems, with installations in this sector increasing from 67 MW in 2009 to 378 MW in 2010, due to continuing deployment under the Solar Homes and Communities Plan, the availability of Solar Credits under the Renewable Energy Target, as well as feed-in tariffs. Total installed capacity in Australia reached 570,9 MW. The largest installed capacity of PV in Australia is now for distributed grid-connected applications. During 2010, PV capacity reached about 1 % of total national electricity generation capacity, with about 20 % of new electricity generation capacity installed during the year being PV.

Australian Government support programmes impacted significantly on the PV market in 2010. In June 2010, the 45 000 GWh Renewable Energy Target (RET) was separated into two parts, to commence on 1 January 2011 – the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES). The LRET, covers large-scale renewable energy projects like wind farms, commercial-scale solar and geothermal, and the SRES covers small generation units (small-scale solar photovoltaic, small wind turbines and micro hydroelectric systems) and solar water heaters, and can create small-scale technology certificates (STCs). Solar Credits apply to the first 1,5 kW of capacity for PV systems connected to a main electricity grid and up to the first 20 kW of capacity for off-grid systems. Output from capacity above 1,5kWp is eligible for 1 STC per MWh. Solar Credits work by multiplying the number of certificates that these systems would generally be eligible to create under the standard deeming arrangements – for PV systems up to 100 kW installed capacity, 15 years' worth of STCs can be claimed up front. The multiplier can be changed by Government to influence demand for small-scale PV systems.

The Solar Homes and Communities Plan (SHCP) provided rebates of 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. Rebates up to 5 000 AUD were available for system upgrades (at 5 AUD/W), if no previous rebates had been received. Although the programme ended on 9 June 2009, a very large number of pre-approval applications were received in the closing days, and installations under the programme are still occurring in 2011. The final cost of the programme is estimated to be in the order of 1,1 billion AUD.

A range of State based feed-in tariffs applied across Australia in 2010. The changes that occurred in 2010 were:

- The ACT feed-in tariff for systems up to 30 kW decreased to 0,457 AUD/kWh for systems installed as of the 1 July 2010.
- The New South Wales 0,60 AUD/kWh gross feed-in tariff commenced on the 1 Jan 2010 (although system owners only received the tariff once appropriate meters had been installed), then was dropped to 0,20 AUD from 27 Oct 2010.
- The Western Australian 0,40 AUD/kWh net feed-in tariff commenced on the 1 Aug 2010. This feed-in tariff is paid in addition to the rate paid by retailers under the Renewable Energy Buyback Scheme.

Six Solar Cities with PV components to their projects installed PV systems in 2010. A total of 1 406 kW of residential PV systems and 739 kW of large-scale «iconic» or commercial systems were installed under the programme. Many cities are now entering the final reporting and analysis phase of their projects. In total 17,4 million AUD were provided by the Australian Government for the Solar Cities in 2010, with State and local governments as well as energy utilities and business also providing funding.

The Australian Government's National Solar Schools Programme (NSSP) assists schools to take practical action in the fight against climate change. It offers eligible primary and secondary schools the opportunity to compete for 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.

In May 2009 the Australian Government announced a call for 1 GW of solar generation via four solar power stations (solar thermal and PV). The Solar Flagships Programme is split over two funding rounds with the first round to target 400 MW of electricity generation. The Government plans to announce the projects that will be offered funding in Round 1 of the Solar Flagships Programme around the middle of 2011.

Bushlight is an Australian Government-funded national, non-profit project that 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. In 2010, Bushlight installed nine new renewable energy systems, with a combined total output of 121,6 kW of PV. Bushlight upgraded one system with an additional 2,7 kW. During 2010 Bushlight's maintenance programme provided ongoing support for 265 renewable energy systems, located in 220 communities. In 2010 a total of 3 378 kW of PV was installed in remote areas of Australia under the Renewable Remote Power Generation Programme (RRPGP). This programme has now closed.

Throughout 2010 State and Territory PV programmes were active in the Northern Territory, Queensland, South Australia, Tasmania, Victoria and Western Australia. A total of 641,3 million AUD were spent by the Australian and State and Territory Governments on PV R&D, demonstration and market stimulation, with the latter accounting for 78 % of expenditure, largely due to rebates provided through the Solar Homes and Communities Plan.

Austria (AUT)

The Austrian PV market more than doubled in 2010 compared to 2009. During 2010, grid-connected PV systems with a total PV power of 42,7 MW were installed, representing well over 99 % of the annual PV market. The cumulative installed PV capacity in Austria reached 95,5 MW at the end of 2010. Grid-connected applications increasingly dominate the market for PV, accounting for more than 96 % of the cumulative installed capacity by the end of 2010.

The revised Green Electricity Act (GEA) forms the framework for national PV implementation in Austria. The nationwide feed-in tariff system for electricity introduced under the GEA is financed by all consumers of electricity via supplements on the electricity price and an obligatory purchase price for

Green Electricity that is paid by electricity dealers. The amount paid under the 2010 PV feed-in tariff increased to approximately 13,8 million EUR, an increase of 14 % over the previous year. Average feed-in tariffs were reduced by 7,5 % compared to 2009. The PV electricity produced climbed from about 21 GWh to 26,3 GWh.

Besides the federal feed-in tariff scheme, an initiative launched in 2008 – the national Fund for Climate and Energy – provided rebates for newly installed private PV systems up to 5 kW installed capacity. In 2010 17,8 million EUR were granted under this funding scheme, leading to an installed capacity of over 11 MW.

Each Austrian province is also running regional PV 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 where the installation is not supported by the federal feed-in tariff scheme. In 2010 the regional funding initiatives amounted to about 39,6 million EUR and helped to install a total PV capacity of about 22,6 MW.

Canada (CAN)

Canada's total installed PV capacity more than tripled to 291,1 MW in 2010 compared to 2009. Total PV sales in Canada in 2010 were 196,6 MW, an almost 220 % increase over the previous year. Over 87 % of these sales were grid-connected applications, mostly large-scale – with 13 % being residential and building integrated applications, and 74 % for large ground-mounted utility scale systems that were stimulated by the Ontario Power Authority (OPA) Feed-in Tariff programme. Two years ago around 80 % of installed PV systems in Canada consisted of off-grid applications; now around 80 % of applications are grid-connected.

Ontario was the heart of PV market growth in Canada during 2010. Grid-connected PV applications installed on buildings in Ontario in 2010 amounted to 24,94 MW whereas the corresponding figure for the remainder of the country was 0,554 MW. Large-scale, grid-connected centralized installations amounted to 146,174 MW in 2010, all in Ontario. Operators receive a feed-in tariff rate of 0,42 to 0,44 CAD per kWh. In 2010, the world's largest solar PV facility was built in Ontario – the Enbridge and First Solar 80 MW Sarnia Solar Project. Ontario's Feed-In Tariff programme, managed by the OPA, is divided into two streams: one targeting the small, medium and large renewable energy projects (larger than 10 kW) referred to as the FIT Programme, and the other targeting very small renewable projects (less than 10 kW) such as home or small business installations and referred to as the microFIT Programme. Prices paid for renewable energy generation under FIT and microFIT programmes vary by energy source and take into account the capital investment required to implement the project. Under the programme, solar PV can enter into a 20 year contract to receive a fixed price of up to 0,802 CAD per kWh for the electricity generated. As of December 2010, the OPA had received, under the FIT programme, 3 656 applications representing about 4 886 MW of PV generating capacity. Under the microFIT programme, the OPA had received 18 176 applications representing 166 MW of generating capacity (99 % of which was for PV). Given limited electricity transmission capacity and an extremely large number of applications, a transmission planning process, known as the Economic Connection Test (ECT), was created to facilitate generator investment in new transmission ‹enabler› lines. A comprehensive regulatory evaluation of these new electricity network investment proposals would be conducted by the Ontario Energy Board (OEB), the province's regulatory authority.

Canada Mortgage and Housing Corporation's (CMHC's) EQuilibrium™ Sustainable Housing Demonstration Initiative brings together the private and public sectors with the goal of developing homes that are designed and constructed based on the principals of occupant health and comfort, energy efficiency, renewable energy production, resource conservation, reduced environmental impact, and affordability. Sustainable Development Technology Canada (SDTC) – an arms-length foundation that operates as a not-for-profit corporation, established by the Government of Canada in 2001 to support the development and demonstration of innovative technological solutions, continued in 2010 to invest in clean energy technology solutions. SDTC is a federally-funded body that leverages private sector resources to demonstrate market-ready technologies including solar photovoltaic.

China (CHN)

About 500 MW of PV were installed in China in 2010, a more than threefold increase on 2009 levels. Total installed capacity in China reached about 800 MW. The Chinese Government is now providing strong support via incentive policies and financial measures to expand the domestic Chinese PV market, in an attempt to better balance domestic industrial production of PV and local PV market demand. Further, as result of the earthquake and nuclear power issues that occurred in Japan, the government has raised the targets for cumulative installed PV in the country – from 5 GW to 10 GW by 2015, and from 20 GW to 50 GW by 2020.

Currently, there are two types of government-supported PV projects in China. Large-scale PV power plants, mainly located in western China, receive a power purchase arrangement for exported electricity. There is no common feed-in tariff in China, only these specific buyback arrangements for certain projects. For the period 2008 – 2012 some 800 MW to

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900 MW of large-scale PV projects are envisaged, with power purchase rates ranging from 0,73 CNY/kWh to 4,0 CNY/kWh.

Distributed PV, mainly in the east of China, receives a capital investment subsidy and the projects can also offset the purchase of grid electricity. For the period 2009–2012, under the PV Buildings and Golden Sun projects, some 1 154 MW of PV projects are envisaged, attracting a 50 % capital subsidy and the ability to offset purchase of grid electricity.

The Chinese PV market is forecast to grow from an annual installation of 1,2 GW in 2011, to 2 GW from 2012 through to 2015, increasing to 12 GW by 2020.

Denmark (DNK)

By the end of year 2010 Denmark (including Greenland) had about 7,1 MW of PV installed in total. Grid-connected distributed systems make up the majority (90 %) of PV systems in Denmark. In Greenland stand-alone PV plays a major role as the power source for remote signaling and for the telecommunication network.

Denmark has no general incentive for reducing the investment cost of PV systems but has a net-metering scheme set by law for private households and institutions. Due to increasing taxes on electricity and the increased retail electricity prices, the net-metering scheme is becoming more and more attractive, driving the PV market as illustrated by an annual market increase from 2009 to 2010 of more than 50 %. Many new commercial actors are becoming active.

The EU directive on energy consumption in buildings, minted into a revised national building code in 2005 and moved into force early 2006, specifically mentions PV and allocates PV electricity a factor of 2,5 in the calculation of the energy foot-print of a building. Over the last year or so it has been possible to detect some tangible impact from this on PV deployment, with the trend strengthening, as developers, builders and architects included BIPV in projects due to the building codes. Ongoing political discussions both on the EU level and nationally point to a tightening of the building codes, which may further promote BIPV in Denmark.

France (FRA)

During 2010, 719 MW of PV were installed in France (mainland France, Corsica and the four French overseas departments Guadeloupe, Guyane, Martinique and Réunion), compared to the 155,5 MW installed during 2009. In mainland France, 91 % of the photovoltaic systems in service are less than 3 kW installed capacity. These systems represent 42 % of the total installed PV capacity.

The development of large ground-mounted PV installations initiated over the course of the two previous years continued in 2010. 78 ground-mounted systems of over 500 kW installed capacity were connected to the electricity grid in mainland France, with 16 of these plants being larger than 5 MW. Cumulative PV capacity in France at the end of 2010 was 1 054,3 MW. During 2010, PV capacity reached a little less than 1 % of total national electricity generation capacity, with about 23 % of new electricity generation capacity installed during the year being PV. The heavy demand for PV from private individuals and investors has not been met by the capacity of the national electricity grid operator (ERDF) to absorb all of the applications for connection to the grid. At the end of 2010, about 75 000 systems were awaiting connection throughout France (mainland and the overseas territories), with a potential for an additional 4 150 MW of installed capacity.

Public initiatives structured and supported the expansion of the PV market during 2010: these included the feed-in tariff with a highly specific orientation towards building integration, the income tax credit of 25 % of the amount of the investment in PV system goods (this was 50 % until 29 September 2010) up to a cap of 8 000 EUR per taxpayer (16 000 EUR for a couple), the ADEME-FACE contracts for off-grid systems and various regional and local government support measures.

ISRAEL, Mekorot water company, Eilat

A revised and more robust feed-in tariff scheme was instigated in January 2010, with the new decreased tariffs coming into force in March 2010 and also retroactively applied to installations coming on line after 15 January 2010. A further downwards revision of the feed-in tariffs occurred in August 2010, effective from 1 September 2010. In addition, a reduction in the tax credit for private individuals from 50 % to 25 % took place in September, applicable from 1 October 2010 (this rate will be reduced to 23 % in 2011).

In conjunction with these changes and in order to avoid the formation of a speculative bubble, a general review of the photovoltaic sector in France was undertaken. The ‹Mission on the regulation and development of the photovoltaic sector in France› made a number of recommendations including the progressive reduction of both the feed-in tariffs and the tax incentives for investment. On 9 December 2010 a decree was promulgated to suspend the obligation to purchase PV electricity for a period of three months, from PV systems with an installed capacity of more than 3 kW. The rationale for this moratorium was to initiate discussions amongst all players in the PV sector regarding the lowering of feed-in tariffs or the implementation of a quota system, leading to a new regulatory framework in March 2011. Analysis carried out by the electricity grid operators, ERDF and RTE, revealed that 7 389 projects were impacted by the moratorium, with a potential installed capacity of 2 053 MW. Furthermore, the call for tenders launched by the government in 2008, for the construction of a total of 300 MW of PV distributed over 27 regional power plants by 2011, was declared void.

Germany (DEU)

Market support measures continued to significantly accelerate the installation of grid-connected PV systems in Germany during 2010, resulting in 7 406 MW of new grid-connected PV capacity for the year, bringing the German cumulative capacity to 17,37 GW. This represents a growth in the annual market of 95 % and an increase in the cumulative installed capacity of almost 75 %.

The main driving force behind the robust PV market in Germany remains the long-standing Renewable Energy Sources Act (EEG). In terms of achieving expansion targets for renewable energies in the electricity sector, the EEG has proved to be the most effective funding instrument at the German Government’s disposal. It determines the procedure for grid access for renewable energies and guarantees favorable feed-in tariffs for them, paid by the electricity utilities.

For PV, the feed-in tariff depends on the system size and whether the system is ground-mounted or attached to a building. Since 2009, there is also a tariff for self-consumption of PV electricity. The rates are guaranteed for an operational period of 20 years. Initially, a steady yearly reduction of the PV feed-in tariffs was foreseen. A mechanism was then introduced to adapt the EEG tariff to the market growth. Under this scheme, the reductions are increased or decreased if the annual market deviates from a predefined corridor. For 2009 this corridor was defined to be between 1 000 MW and 1 500 MW – which was significantly exceeded as the market reached about 3 800 MW. For 2010 to 2012, a new corridor of between 2 500 MW and 3 500 MW was defined. Furthermore, for 2010 two additional reduction steps were agreed to adapt the tariff to the decreasing PV system price level. This resulted in an overall feed-in tariff price reduction of roughly 1/3 from the end of 2009 to early 2011. With over 7 000 MW of PV installed in 2010 the new corridor was again significantly surpassed. Hence it was decided to implement the reduction foreseen for 2012 ahead of time.

Beside the EEG support for the market deployment of PV installations, the significant decrease of system prices continues to make PV systems economically more and more attractive for end-users. An analysis published by BSW-Solar, the German Solar Industry Association, shows that the average price for PV roof-top systems of less than 100 kW installed capacity was 2 724 EUR/kW in the last quarter of 2010. Following the price reduction of 25 % from 2008 to 2009 this is a further drop of 13 % from 2009 to 2010.

In addition to the EEG, PV in Germany receives support from other sources – local fiscal authorities provide tax credits for PV investments, and the state owned bank KfW-Bankengruppe provides loans for individuals as well as for local authorities.

Israel (ISR)

During 2010 about 45 MW of PV were installed in Israel, more than double the previous year’s annual market, bringing the cumulative installed capacity to over 69,9 MW. Nearly all the PV systems installed were grid-connected. Small and medium-sized grid-connected systems now dominate the Israeli cumulative installed PV capacity with about 95 % of the total.

Since July 2008, when the feed-in tariff was enacted by the government, there has been a dramatic increase in the installation of PV systems country-wide. 2010 was the second full year of the feed-in tariff scheme. With no statutory control over who may install systems (so long as the actual connection to the grid was approved) the number of installation companies dramatically increased to about 120. Inconsistent government policy concerning extending and raising quotas for installed PV contributed to uncertainty within the industry; with many of the smaller companies not lasting long.

Initially, enthusiasm was such that the original quota for smaller commercial systems was soon over-subscribed, whereas the quota for residential systems was under-subscribed. This was largely due to the different profit margin available to the installation companies according to the types of systems. A feature of the blossoming market in Israel has been the aggressive and direct marketing tactics of the industry, for example targeting one particular market niche – farmers, with sizable roof space available and a promise of extra ‹retirement income›. The industry has also been active in lobbying for higher quotas, increased tariffs for larger systems and changes in land-use legislation such as permission to use agriculturally-zoned land for power stations. Opposition to larger quotas due to the overall cost to the economy has come from the Ministry of Treasury and some other players.

Italy (ITA)

In 2010, 2 321 MW of PV power were installed in Italy, more than three times the size of the market in 2009. Cumulative installed PV power reached over 3,5 GW. Sworn declarations of construction completion recorded until end 2010 point to a further 54,106 installed PV plants, corresponding to a declared capacity of 3 771 MW, not yet in operation. The grid-connected distributed and grid-connected centralized PV power systems markets continue to grow rapidly and now account for almost 44 % and 56 % respectively of the total installed PV capacity in Italy. Italy’s very attractive incentive scheme, the Conto Energia Programme, continued to drive the market during 2010. Some 744 million EUR were allocated for feed-in tariff payments during this third phase of the programme throughout 2010.

The programme represents a long-standing sustained approach to stimulation of the market. The first phase, Primo Conto Energia, defined through two governmental decrees issued in 2005 and in 2006, was completed toward the end of 2009 with 5 733 PV installations (corresponding to about 165 MW). The second phase, Nuovo Conto Energia, defined through a governmental decree issued in February 2007 resulted in a cumulative total (Nuovo and Primo) of 153 282 PV plants, corresponding to about 3 247 MW.

The third phase of the programme, adopted by Ministerial decree on 6 August 2010, has defined the PV feed-in tariffs for the period 2011 to 2013. The feed-in tariff reduction introduced within this third phase, and expected from 2011, caused a sharp increase in the number of installations before the end of 2010. The salva alcoa decree guaranteed 2010 feed-in tariffs for plants installed during 2010 but only needing to be operational by June 2011.

Due to the dramatic PV market growth in Italy, the governmental target of 8 GW of PV installed by 2020 is going to be reached during 2011. As a consequence, a new decree (the fourth Conto Energia) issued in May 2011 has redefined a target of 23 GW by 2016, annual caps for large PV plants and a significant reduction of feed-in tariff prices.

Japan (JPN)

During 2010 a total of 991 MW of PV were installed in Japan, more than double what was installed the previous year. Most of these installations (around 974 MW) continued to be grid-connected distributed, mainly residential, PV systems, with a further 12,6 MW comprising grid-connected centralized plants. The strong market growth can be attributed to the subsidy programme for residential PV systems, continued in 2010 after commencing in 2009, and the programme to purchase surplus PV electricity at double the retail electricity price from systems of less than 10 kW, that commenced in November 2009. In 2010 cumulative installed PV capacity in Japan exceeded 3,6 GW, more than 1,5 % of total national electricity generation capacity.

The Japanese PV market is clearly dominated by grid-connected distributed PV systems, mainly for private houses, collective housing or apartment buildings, public facilities, industrial and commercial facilities, and buildings. This market segment has been driven by residential PV systems with a capacity of 3 KW to 5 kW, as well as PV systems with a capacity of 10 KW to 1 MW for public, industrial and commercial facilities. Residential PV systems account for 81,4 % of the grid-connected market in Japan. However, installations of medium and large-scale PV systems in public and industrial facilities as well as commercial buildings have been increasing, mainly with the support of the Ministry of Economy, Trade and Industry (METI). PV systems on public facilities, established by the national and local governments, account for 7,4 % of the grid-connected market, while PV systems for industrial and commercial use account for 11,1 %. Grid-connected centralized PV systems account for 1,3 % of the grid-connected market in Japan. The national government has provided subsidies and preferential tax treatment for public and industrial PV systems. Consequently more PV

Japan, AEON-Rinku

NIER, Incheon, Korea

systems are now being installed in public, industrial and commercial facilities, as well as electricity utility facilities. With the expansion of the PV system user population, a large-scale industrial PV market of systems greater than 100 kW installed capacity, such as on the roofs of large factories, is emerging. The off-grid domestic PV system market is small in size, and applies to residences in remote areas and some public and industrial facilities. The off-grid non-residential PV system market operates without needing any subsidies.

The Japanese government has announced its intention to strategically strengthen the dissemination of renewable energy as a high priority issue for the Japanese economy and domestic energy supply. Based on this policy, METI has drawn up the draft design of legislation for the new feed-in tariff programme to accelerate the dissemination of PV and other renewable energy sources. An increasing number of other ministries and agencies such as the Ministry of Education, Culture, Sports, Science and Technology (MEXT), the Ministry of the Environment (MoE), the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF) have also introduced PV systems in their programmes.

More and more local governments began to provide their own support programmes for the introduction of PV systems, alongside the subsidy programme for residential PV systems by the national government. Some 655 municipalities now have their own support programmes. In addition to public facilities developments, some local governments are also subsidizing PV installations on industrial facilities, while others have supported the introduction of MW-scale PV power plants. Electricity utilities are also constructing MW-scale PV power plants. About 100 MW of these plants are scheduled to be operational by 2012.

Within Japan there has been an increasing recognition that PV systems will become the new products for mass distribution. The housing industry, the construction industry, the real estate industry and the distribution industry have all started making a significant move into the PV market. In the housing industry, middle-sized housing manufacturers, in addition to major pre-fabricated housing manufacturers, have actively promoted PV systems as standard features on their houses. This has strengthened the sales of houses equipped with PV systems. Major pre-fabricated housing manufacturers have introduced PV systems on rented apartments. In the construction and real estate industries, developers have started introducing PV systems in their condominium and building developments. In the distribution industry, a number of home electric appliance stores and major supermarkets have begun sales of residential PV systems, creating new strong distribution channels.

Korea (KOR)

The cumulative installed power of PV systems in Korea increased to 655,6 MW by the end of 2010. The annual installed PV power during 2010 reached 131,2 MW, slightly less than the amount installed in 2009. Grid-connected centralized systems accounted for 79 % of the total cumulative installed PV power. Grid-connected distributed systems accounted for 20 % of the total cumulative installed PV power. Grid-connected systems are mainly installed under the feed-in tariff programme and the One Million Green Homes programme, with the budget for market incentives increasing by more than 30 % compared to 2009. The share of off-grid non-domestic and domestic systems has continued to decrease to about 0,9 % of the total cumulative installed power. During 2010, PV capacity reached about 0,8 % of total national electricity generation capacity, with about 4,8 % of new electricity generation capacity installed during the year being PV.

The aims of Korean new and renewable energy policy are to enhance the level of self-sufficiency in energy supply, to meet the challenges of climate change and to consolidate the infrastructure of the renewables industry. The goal of renewables deployment is to achieve a 4,3 % share of total primary energy supply by 2015. PV still remains a prioritized area. A number of government programmes are pertinent to the deployment of PV.

The One Million Green Homes Programme aims for the construction of one million green homes utilizing PV as well as solar thermal, fuel cells, wind, bio-energy and geothermal by 2020. Single-family houses and multi-family houses including apartments can benefit from this programme. The government provides 60 % of initial PV system cost for single-family and private multi-family houses, and 100 % of the cost for public multi-family rental houses. By the end of 2010, a total of about 68 MW of PV capacity had been installed, involving around 65 000 households. During 2010, 24 MW of PV were installed, benefitting 26 360 households.

The feed-in tariff rate has been reduced considerably since 2008, and the cap was increased from 100 MW to 500 MW. Beneficiaries can choose the payment period to be either 15 years or 20 years. In 2009 139 MW of PV were installed under this scheme; this fell to 61 MW in 2010. The feed-in tariffs for 2010 and 2011 were reduced by 10 % to 15 % compared with 2009. For BIPV a 10 % bonus is provided; however a BIPV system larger than 1 MW is counted as a ground-mounted system. It is planned that a Renewable Portfolio Standard will replace the feed-in tariff scheme from 2012, at which time the annual market is expected to again be larger than 200 MW and with grid parity anticipated by 2020.

In addition to the above, the General Deployment Subsidy Programme provides 50 % of the installation cost of PV systems with a capacity below 50 kW, and 80 % of the initial cost for special purpose demonstration and pre-planned systems, the so-called Test-period deployment subsidy programme. In 2010, 41 PV systems with a total capacity of 0,6 MW were installed in schools, public facilities, welfare facilities and universities. The Regional Deployment Subsidy Programme provides government support of 50 % of the installation cost of PV systems owned and operated by local authorities. The RPS Demonstration Programme is planned to run for three years from 2009 until 2011, before the commencement of the RPS in 2012. The total capacity to be installed is fixed at 101,3 MW. Six electricity companies have constructed their own PV plants or purchase PV electricity from private operators under this programme with 17,9 MW of PV installed in 2010.

Under the Public Building Obligation Programme, new public buildings larger than 3 000 square meters must spend 5 % of their total construction budget installing renewable energy facilities. In 2010, approximately 12 MW of PV were installed under this programme. As the government pursues its New Administration-Oriented City Plan and the Plan for Public Enterprise Relocation, new public buildings are planned all over Korea and it is anticipated that this programme will contribute to the expansion of the Korean PV market.

Malaysia (MYS)

By the end of 2010 Malaysia had a total installed PV capacity of about 12,6 MW, of which 1,6 MW were grid-connected. During 2010 there were about 500 kW of grid-connected PV systems installed and an estimated 1 MW of off-grid systems. The single largest grid-connected PV system commissioned in 2010 was a 101,5 kW system located on the island of Penang.

Until 2010, the main driver of the grid-connected PV market was the MBIPV Project. Under the Renewable Energy Act 2011, a feed-in tariff, to be implemented around the final quarter of 2011, will be the next and main catalyst for grid-connected PV growth in the country for a number of years.

2010 marked the end of the MBIPV Project. The Project was launched by the Government of Malaysia in July 2005 to reduce the long-term cost of BIPV technology application through widespread and sustainable BIPV market development programmes. Three objective targets were established at the onset of the project:

(i) 330 % increase in BIPV installed capacity against baseline,
(ii) 20 % reduction of BIPV system unit cost from baseline, and
(iii) Incorporation of a new BIPV programme in the 10th Malaysia Plan.

By the end of 2010, the actual achievements were:

(i) 539 % increase in BIPV installed capacity against baseline,
(ii) 50 % reduction of BIPV system unit cost from baseline, and
(iii) Introduction of the feed-in tariff incentive in the 10th Malaysia Plan.

The MBIPV Project is widely recognized locally and internationally for its widespread and sustainable impact, and the ability for it to be replicated in other countries with similar economic backgrounds.

Under the new feed-in tariff programme, Malaysia is expected to realize some 1 250 MW of grid-connected PV installations by 2020.

Mexico (MEX)

During 2010 5,6 MW of PV were installed in Mexico, bringing the cumulative installed capacity to around 30,6 MW. It is estimated that the share of grid-connected PV systems installed was about 70 % of the annual market in 2010. The first 1 MW grid-connected centralized PV plant was developed during 2010.

Although no funding has been allocated to promote PV installations and feed-in tariffs are not

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offered, the profile of grid-connected PV in Mexico has been raised during 2010. A 135 kW grid-connected PV system was installed on the roof of the hotel where the COP 16 summit took place in Cancun. A 30 kW grid-connected system was installed at the Technology Museum of the national electricity utility CFE in Mexico City. Meanwhile, MW-size projects are at different stages of development in at least eight regions of Mexico, either for electricity self-supply or for export of electricity to the US, mainly for the Californian market.

The regulatory framework has been significantly bolstered with the substantial increase in the allowable capacity (to 500 kW) of renewable technologies and cogeneration systems that can be connected to the grid and also receive the benefits of net metering. Former regulations allowed the connection of PV systems up to 30 kW in size for commercial systems and office buildings and up to 10 kW installed capacity for domestic systems.

On the back of these positive developments the Mexican PV market for 2011 is estimated to reach 15 MW, triple the size of the 2010 market.

The Netherlands (NLD)

During 2010 about 21 MW of PV were installed in the Netherlands, bringing the cumulative installed capacity to 88 MW. This represents a doubling of the annual market compared to the previous year. PV electricity in the Netherlands represents about 0,05 % of the total electricity production.

The market increase in 2010 compared to previous years is partly due to the release of a backlog of grants following the start of the new subsidy scheme (SDE) in 2008. Grants from previous years still remain in the pipeline. The subsidy scheme has now been revised and systems below 15 kW are no longer supported. However there is an increasing amount of small and medium scale PV systems being installed without subsidy, with the slightly decreasing price of solar modules in 2010 playing an important role. Also significant have been the initiatives that bundle customer PV system demand and purchase batches of PV modules for more favourable prices.

Throughout the Netherlands there are increasing initiatives from the regional public authorities (cities and provinces) to install PV as part of efforts to reduce their carbon foot-print.

Norway (NOR)

About 0,4 MW of PV were installed in Norway during 2010, mostly in off-grid systems, with the annual market remaining at much the same level as the previous five years. Off-grid domestic applications account for over 92 % of Norway's cumulative installed PV capacity of about 9,1 MW. While there are no public funds earmarked for stimulating the market introduction of PV in Norway, PV R&D receives significant support relative to other countries.

The main market for PV in Norway continues to be related to off-grid applications – both the leisure market (cabins, leisure boats) and the professional market (primarily lighthouses/lanterns along the coast and telecommunication systems). Exceptions are a few business and public actors who have integrated PV in large buildings, and some private homebuilders who have installed PV systems on private grid-connected houses. Norway's largest building integrated PV project so far commenced construction in 2010. The 60 kW, 470 square meter system is integrated as part of the roof and southern wall in Oseana, a combined culture and arts centre located in Os on the Norwegian west coast. The building represents the latest in modern architecture and is expected to become a landmark and major tourist attraction after its opening in June 2011.

Portugal (PRT)
Portugal's annual PV market again fell slightly compared to the previous year. About 28,5 MW of grid-connected applications were realized (almost the entire annual market) and the cumulative installed capacity rose to 130,8 MW. Grid-connected centralized systems account for 72 % of the cumulative installed capacity in Portugal, and grid-connected distributed systems make up about 25 %. In 2010, about two thirds (19 MW) of the new PV capacity were installed under the micro-generation scheme, while the remainder were large PV power plants, typically above 1 MW in size.

In Portugal, the main market-driven instrument for promoting renewable electricity, including PV, is a feed-in tariff mechanism, based on different frameworks according to system size:

- the Independent Power Producer (IPP) framework, in force since 1988, with no upper limit for system capacity
- the micro-generation scheme (2007), for system capacities up to 10 kW
- the mini-generation scheme (2010), for capacities up to 250 kW.

During 2010, under the IPP framework, 150 MW of renewable energy capacity (75 blocks of 2 MW each) were awarded through public tender. In December 2010 the mini-generation scheme was adopted for PV systems with installed power up to 250 kW (but also greater than the micro-generation capacity), specially oriented towards small and medium enterprises. With a 500 MW target by 2020 (50 MW per year), this scheme involves a simplified, web-based licensing process and the feed-in tariffs are based on three different capacity ranges: up to 20 kW, from 20 kW to 100 kW, and from 100 kW to 250 kW.

Spain (ESP)
During 2010 annual installed PV power in Spain rebounded somewhat from the collapse of 2009 to reach 392 MW, of which over 99 % were grid-connected. By end 2010, about 70 % of PV plants in Spain were larger than 1 MW. Two important Royal Decrees were published during 2010 that have and will continue to impact the Spanish PV market: Royal Decree 1565/2010 and the Royal Decree Law 14/2010.

Royal Decree 1565/2010 has amended the economic regime contained in Royal Decree 1578/2008 for photovoltaic installations in operation, putting electricity into the grid and registered in the Administrative Registry of Producers after 30 September 2008. Feed-in tariffs have been amended as follows: 45 % reduction for ground-based PV installations, 25 % reduction for large roof-top installations (> 20 kW), and 5 % reduction for smaller roof-top systems. With regard to PV systems in operation, putting electricity into the grid and registered before 30 September 2008, their economic regime has also been amended by cancelling the feed-in tariff after 25 years of operation. Other amendments include a definition of a ‹substantial change› in installations whereby the plant may become ineligible to continue to receive the feed-in tariff set in the previous economic regime.

The feed-in tariff paid to Spanish PV installations was also reduced through limiting the operational hours, via Royal Decree Law 14/2010. Operational hours are limited to 1 250 hours per year for fixed systems, 1 644 hours per year for single-axis tracking systems and 1 707 hours per year for two-axis tracking systems. Surplus generation outside these hours is purchased at regular wholesale electricity market prices. The limitation applies for the next three years; however, to compensate, the total period for which the feed-in tariff can be obtained has been extended three years. In addition, a network toll has been introduced, applicable to all electricity generation plants, with PV plants being exempt for the first three years.

These changes followed months of uncertainty. Applying the legislation retrospectively to existing installations has been controversial, with fears that the changes will jeopardize the financial position of some installations. However, it is hoped that the new legislation will again provide the Spanish renewable sector with the legal certainty needed for the development of projects and provide a much-needed boost after months of impasse.

In June 2010, Spain adopted a national action plan for renewable energies 2011 – 2020 (PANER). According to the plan, by 2020 the share of renewable in final energy consumption should increase to 20 %. According to the PANER, 3,6 % of the Spanish electricity energy demand in 2020 should be met by PV electricity.

Sweden (SWE)
Annual installed PV power in Sweden in 2010 reached 2,7 MW – a threefold increase compared with the market the previous year. Grid-connected installations

accounted for close to 80 % of the market. The cumulative installed power of PV systems in Sweden increased to 11,4 MW by the end of 2010.

The large increase in the annual market was due to funds from the second direct capital subsidy scheme (started in mid 2009) beginning to reach the system installers, with several projects that were initiated in 2009 being put into operation in 2010. A total budget of 222 million SEK has been set aside for the subsidy over three years, to cover 60 % (55 % for large companies) of the installation cost, including both material and labor. Other positive factors for grid-connected installations were the elimination in April 2010 of the fee charged by distribution system operators (DSOs) for small PV systems and the requirement that the DSOs now pay for the necessary electricity meters. With the introduction of the first subsidy in 2005, directed only at public buildings, a number of larger grid-connected distributed systems were installed. The second subsidy, which will continue until the end of 2011, is open to all types of installations. Consequently more small, private PV systems are now being connected to the grid. A notable decrease in the installation rate occurred in the gap between the two subsidy schemes, highlighting the dependence on public support schemes.

Sweden also has a unique local feed-in tariff programme, in which the local electricity utility company in the Sala-Heby municipal area has agreed to buy PV electricity from a small PV power community at a price higher than the normal market price.

Historically, the Swedish PV market has almost entirely consisted of a small but stable off-grid market based on PV systems for recreational cottages. This unsubsidized domestic off-grid market is still stable and is growing slightly, probably due to the lower module and system prices and a growing interest in PV in Sweden.

There is some apprehension in Sweden as to what may happen to PV installation rates when subsidies end after 2011. A proposal for the introduction of monthly net-billing has been forthcoming from the PV industry and is being considered at the Ministry of Enterprise, Energy and Communications (Näringsdepartementet).

Switzerland (CHE)
Annual installed PV power in Switzerland in 2010 reached 37,3 MW – a 45 % increase in the annual market compared to the previous year. Nearly all the systems installed were grid-connected and grid-connected capacity now makes up over 96 % of Switzerland's cumulative installed PV capacity of 110,9 MW. During 2010, PV capacity reached about 0,6 % of total national electricity generation capacity.

Larger installations (> 100 kW) are usually flat-roof mounted on commercial buildings, offices etc. Tilted

Courtesy BE Netz, Switzerland

roof installations on farmhouses with sizes ranging from 30 kW to more than 100 kW have become more common. The size of residential systems has increased from a de-facto standard in earlier years of 3 kW to up to 15 kW. This trend is associated with using the whole roof facing south (SE to SW) rather than only a part of it, as the Swiss feed-in tariff has no upper limits concerning the size of the installation.

During 2010 the Swiss parliament adopted a revision of the energy law that increased the levy on electricity for the feed-in tariff scheme by 50 %. Swiss Government reduced the feed-in tariff price by 18 %. Consequently the cap for the scheme has now risen to around a cumulative 200 MW by 2013.

Besides the successful feed-in tariff scheme, some cantons offer direct subsidies for PV installation, two cantons (Geneva and Basel Stadt) offer their own feed-in tariffs, and Naturemade (certified renewable electricity scheme) and the Solar Stock Exchange continue to operate.

Turkey (TUR)
About 1 MW of PV was installed in Turkey during 2010, with the annual market remaining at a stable level compared to the previous year. Off-grid applications account for 90 % of Turkey's cumulative installed PV capacity of about 6 MW.

As a tangible target, the Energy and Natural Resources Ministry 2010–2014 Strategic Plan aims to reach a 30 % share of renewables (including hydro) in electricity production by 2023. In the light of this striking projection, a rapidly growing PV market in Turkey in the near future is anticipated.

Coming at the end of 2010, the ‹Utilization of Renewable Energy Resources for Electric Production› law consists of incentives for PV and other renewables. PV electricity has been guaranteed to be bought at 0,133 USD/kWh for a 10 year period and additional incentives are available to encourage domestic manufacturing of components (0,008 USD/kWh for PV module integration and mechanical solar

48-MW Copper Mountain installation; credit: Sempra Energy

construction, 0,013 USD/kWh for PV modules, 0,035 USD/kWh for PV cells, 0,006 USD/kWh for the inverter, and 0,005 USD/kWh for materials focusing solar energy on PV modules). It is anticipated that the PV market in Turkey will grow strongly as a result of these measures.

United States of America (USA)

Total PV capacity in the US increased by an estimated 918 MW in 2010 – representing double the growth in the annual market compared to the previous year. Of this market almost 97 % (887 MW) were grid-connected systems. Cumulative installed capacity in the US reached 2 534 MW by the end of 2010. The US market is supporting robust growth in all three grid-connected market segments – residential, commercial and utility-scale.

More than 50 000 PV systems were connected to the grid in 2010, compared to 34 000 in 2009. By the end of 2010, there were more than 152 882 distributed grid-connected PV systems across the US. The capacity of centralized grid-connected PV systems (utility applications) expanded from 66 MW installed in 2009 to approximately 242 MW installed in 2010. The largest utility-scale PV plant in the United States is the Copper Mountain facility in Nevada, with an installed capacity of 55 MW. With over 600 MW of new utility-scale projects expected to begin operation in 2011 this sector is expected to dominate the market, growing to close to 50 % of PV market share.

Two of the major federal policy drivers for growth in PV installations included the 30 % investment tax credit (ITC) and the five-year accelerated depreciation (modified accelerated cost recovery schedule or MARCS). The ITC applies to both residential and commercial installations and the MARCS applies only to commercial installations (although it is also indirectly available to the residential customers of companies that sell PV electricity from third-party owned systems through Power Purchase Agreements). To increase the benefits and accessibility of the ITC, in 2010 federal legislation was enacted that allows PV assets placed in service from 2009–2012 to receive a cash grant from the Treasury Department, worth 30 % of the qualified costs of a PV project, in lieu of the ITC.

Under an amendment to MARCS, eligible PV property placed in service after 8 September 2010, and before 1 January 2012, qualifies for 100 % first-year bonus depreciation. For 2012, bonus depreciation is still available, but the allowable deduction reverts from 100 % to 50 % of the eligible basis.

Also spurring development was the Department of Energy (DOE) Loan Programmes Office, which entered into several loan guarantees for PV manufacturing and power-generation projects. Awards under this programme were funded through the American Reinvestment and Recovery Act (Recovery Act).

The diversity of state markets is a strength of the United States, making it less likely to see the strong boom-bust cycles experienced in many other national PV markets. California installed some 32 % of the new PV capacity in 2010. California and New Jersey, the two largest and most established state markets, together accounted for nearly 50 % of new PV capacity installed in the US during the year. However 16 states each installed more than 10 MW of PV capacity during the year.

In addition to support from federal policies and agencies, PV saw significant advances in the adoption of various state and local policy instruments, including improved net metering and interconnection rules, regulatory acceptance of third-party financing models, renewable portfolio standards (RPS), and performance-based incentives. Net metering activity included a new California law that raised the aggregate cap on net metering from 2,5 % to 5 % of a given utility's peak load. West Virginia adopted an improved net metering policy that raised the capacity limit for commercial and industrial customers to

12 MW Wyandot Solar Farm; credit: PSE&G

500 kW and 2 MW respectively, with an overall programme capacity of 3 % of utility peak load. Utah improved its statewide interconnection rule by introducing standard interconnection agreements, based on system type, and raising the system capacity limit from 25 kW and 2 MW for residential and non-residential systems respectively to a uniform 20 MW. Meanwhile, by the end of 2010, 19 states and Puerto Rico explicitly allowed third-party financing, up from only eight states at the end of 2009. In October 2010, Hawaii joined nine other jurisdictions and utilities in the United States that have adopted a feed-in tariff.

Despite these successes, 2010 also yielded significant challenges for other state and local renewable energy policy instruments. In Florida, for example, four separate incentives for renewable energy expired: a capacity-based solar rebate programme, a production-based tax credit, a capacity-based investment tax credit, and a sales-tax exemption for renewable energy equipment. The Property Assessed Clean Energy (PACE) model, whose adoption by local jurisdictions had accelerated in 2009, experienced a significant setback following a determination in February 2010 by the Federal Housing Finance Authority (FHFA). The legality of feed-in tariffs had also been challenged before the Federal Energy Regulatory Commission (FERC) in proceedings involving the California Public Utilities Commission and three California utilities. A FERC order issued in October 2010 resolved the uncertainty by providing clarifying validation, within strict parameters, for a state-level feed-in tariff.

Electricity utility interest in PV continues to increase in the US. The key drivers are policy—the 30 % ITC at the national level and renewable portfolio standards at the state level. As consumer demand increases and grid parity moves closer in different markets, cooperation between the electricity utility industry and the solar industry is increasing. Several US electricity utilities lease customer roof space for PV generation that is fed directly back to the grid, often with the goal of placing systems strategically in the electricity network for grid support benefits. This emerging utility business now blurs the line between utility-scale and distributed PV. One of the largest utility roof-top programmes is in California and has a target capacity of 250 MW, all in 1 MW to 5 MW segments.

In February 2011, Secretary of Energy, Steven Chu announced the SunShot Initiative, a collaborative national initiative to make solar energy technologies cost-competitive with other forms of energy by reducing the cost of solar energy systems by about 75 % before 2020. In addition to investing in improvements in solar technologies and manufacturing, SunShot focuses on integrating systems into the electricity grid and reducing hardware and non-hardware balance of system costs. Several financial analysts have projected US PV installations to increase to 3,25 GW per year by 2012. Sustained growth in US installations is likely to be driven by a combination of factors, including state-level policies, the Grant in Lieu of the Investment Tax Credit, and the 100 % first-year bonus depreciation for eligible property under the Modified Accelerated Cost-Recovery System (MACRS).

Other countries

Verifying total market volume and other data for non IEA PVPS countries is challenging. 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. PV is spreading to many new markets, with these countries often following the same policy frameworks as the traditional PV countries. More countries deploying significant quantities of PV should mean a more stable global market development.

Bangladesh

The Government of Bangladesh has been emphasizing the development of solar home systems (SHS) as 50 % to 75 % of homes in the country have no access to mains electricity. Under the Bangladesh Climate Change Strategy and Action Plan 2009 the government is exploring incentive schemes to encourage entrepreneurs who wish to start PV actions, such as the Infra-structure Development Company Ltd. (IDCOL). Through IDCOL and others about 900 000 SHS (PV capacity of about 45 MW) have been deployed so far with about 325 000 of these commissioned in 2010. The target for 2014 is 2,5 million SHS. IDCOL is also aiming for 10 000 PV irrigation pumps, with a capacity of about 80 MW of PV.

Belgium
About 300 MW of PV were installed during 2010, mostly in the region of Flanders, compared with about 500 MW in 2009. PV incentives have been reduced for larger PV systems, and roof-top size systems are favored. In Belgium energy policy is a regional matter, with each of the three regions having specific interests and incentives but also common approaches such as reverse kWh metering up to 10 kW installed PV capacity, fiscal deduction for investment and loans, and green certificates financed by a levy on consumer tariffs.

Bulgaria
The Ministry of Economy, Energy and Tourism (MEE) estimates that about 25 MW of PV were installed during 2010, up from about 5 MW the previous year. Bulgaria has set a national target of 2 GW of PV by 2020 and introduced an attractive feed-in tariff. However the annual degression mechanism of the FiT appears non-transparent leading to uncertainties for investors. At end of 2010 applications totaling about 6 GW had been submitted to grid operators, the tariffs had been reduced and the whole scheme is currently under revision.

Czech Republic
More than 1 GW of PV was estimated to have been installed in the Czech Republic during 2010 due to favorable feed-in tariff conditions with the total installed capacity approaching 2 GW. Initially the Czech Republic had one of the most attractive feed-in tariff schemes in the world at about 12,25 CZK/kWh (about 0,647 USD/kWh) for PV systems up to 30 kW installed capacity and 12,15 CZK/kWh for larger systems – set by the Energy Regulatory Office (ERU), guaranteed for 20 years and funded by a levy on electricity consumer tariffs. Due to the rapid market growth the government has reduced the tariffs to about 50 % of the original values and has retroactively introduced a 26 % to 28 % tax on all PV revenues. In 2011, after a transitional scheme up to March 2011, only PV systems of less than 30 kW installed capacity will be included in the feed-in tariff scheme.

Greece
About 150 MW of grid-connected PV were estimated to have been installed in Greece during 2010, bringing the cumulative capacity to just over 200 MW. Greece has had a very attractive feed-in tariff scheme in operation since 2006 and a current national target of 2,2 GW of PV installed by 2020. At end of 2010 the feed-in tariff was 0,779 USD/kWh for PV roof-tops up to 10 kW in size and guaranteed for 25 years; for systems up to 100 kW the feed-in tariff was 0,625 USD/kWh and for larger systems 0,555 USD/kWh is guaranteed for 20 years. A digression scheme with bi-annual reductions has been published covering up to the end of 2014. Special feed-in tariff conditions are in place for PV systems connected to autonomous island girds. Different conditions with regard to taxation and VAT exist for private households and companies.

India
Estimates for installed PV capacity in India by the end of 2010 range from 30 MW to 100 MW. The Ministry of New and Renewable Energy (MNRE) estimates India to have installed about 50 MW in terms of PV lanterns, solar home systems, street lights and small pumping systems; a further 36 MW are installed as power plants, with about 32 MW being grid-connected and the remaining 4 MW stand-alone power systems. India's Jawaharial Nehru National Solar Energy Mission sets out ambitious targets for solar energy capacities, such as 20 GW by 2022 and 100 GW by 2030, with 90 % of capacity to be grid-connected systems and the remaining 10 % to comprise off-grid systems.

The government has introduced an indicative feed-in tariff guarantied for 25 years at a level of about 0,40 USD/kWh, but has combined this with a ‹blind bidding› process, in which the applicant offers their own discount against the feed-in tariff. The central government has additional support schemes for PV deployment, e.g. the migration scheme at the Central Energy Regulatory Commission (CERC) and the IREDA Small Solar and Roof-top Programme. The first bidding process encompassing 30 installations of 5 MW ran during 2010, and resulted in discounts ranging from 28 % – 39 %. Also a number of PV projects totaling around 85 MW have been selected under the migration scheme at the CERC and some 100 MW under the IREDA scheme.

The respective roles and responsibilities of the central and local governments are not well defined. The states of Rajastan and Gujarat appear to have their own very ambitious plans for PV, for example Rajastan with an immediate target of 500 MW and 10 GW by the end of 2014. Applications in Rajastan at a level of 1,5 GW have been reported received. During 2010, PPA's for around 370 MW of PV have been signed in Gujarat with implementation planned before the end of 2011. A planned 500 MW Gujarat solar park has received applications for 166 MW of capacity.

Slovakia
During 2010 the installed capacity in Slovakia grew from 0,2 MW to around 145 MW. In January 2010 the government introduced a feed-in tariff scheme guaranteed for 15 years; the scheme will be adjusted to developments in PV prices and has already in 2011 been reduced twice. By the end of 2010 the feed-in tariff ranged from almost 0,70 USD/kWh for fully integrated roof-top systems to 0,45 USD/kWh for ground based installations. For installations >100 kW there is a quota of 120 MW (already exhausted in

2010). It is expected that the feed-in tariff reductions and the quota system will reduce future growth considerably.

Slovenia
The amount of installed PV capacity in Slovenia appears to have grown from around 5 MW in 2009 to almost 30 MW by the end of 2010. In June 2009 Slovenia introduced a new 15 year feed-in tariff scheme with differentiated prices (0,40 USD/kWh to 0,60 USD/kWh) and an annual degression rate of 7 %. By end of 2010 the FIT ranged from 0,35 USD/kWh to 0,55 USD/kWh.

Taiwan
During 2010 Taiwan installed about 8 MW of PV, mostly in the form of grid-connected roof-top installations. By the end of 2010 the cumulative installed PV capacity was about 20 MW.
Taiwan has a feed-in tariff scheme for PV, guaranteed for 20 years, administered by the Bureau of Energy, Ministry of Economic Affairs. This is part of the Renewable Energy Development Act (REDA) passed in mid 2009. Initially the feed-in tariff was quite generous at 0,50 USD/kWh (0,38 USD/kWh if combined with the capital subsidy of 1 700 USD/kW available to property owners), but it was later reduced to about 0,35 USD/kWh, applied only to property owners, with system sizes capped at 10 kW. Larger systems and ground based systems have to be approved in a competitive bidding process based on the lowest feed-in tariff offered. Furthermore an annual ceiling has been introduced – to be adjusted every two years – 10 MW for systems up to 10 kW and 60 MW for larger systems, for a total annual cap of 70 MW. It is the intention to favor small scale roof-top PV at the expense of larger-scale systems, particular ground based installations.

Thailand
By the end of 2010 Thailand had a cumulative installed PV capacity of about 50 MW, with about 30 MW being off-grid systems. The annual market during 2010 was about 10 MW, mostly grid-connected systems. A number of PV farms are under construction totaling about 160 MW – with expansion plans up to almost 400 MW – including a 73 MW farm, so far the biggest PV plant in Asia. The 73 MW farm is partly financed by the Asian Development Bank under the very recent Asian Solar Energy Initiative.

Thailand is aiming for a renewable energy contribution of 20 % by 2022. In 2009 a feed-in tariff for PV was introduced in the form of an additional 8 THB/kWh (about 0,26 USD/kWh) on top of the regular tariff of around 3 THB/kWh. The feed-in tariff is guaranteed for ten years and is paid by a small levy on the price of electricity. Other PV support schemes include tax incentives by the national Board of Investment, free technical assistance, investment grants, soft loans and a government co-investment scheme. Thailand is targeting 500 MW of PV capacity by 2020, but has – according to the Ministry of Energy – already received applications for almost 3 GW. As a consequence, towards the end of 2010, Thailand put the deployment of grid-connected PV systems on hold, while deliberating how to control the future development of the PV market without penalizing the ordinary electricity consumer with price hikes.

Brazil has about 20 MW of PV capacity installed of which only about 1 % is grid connected. **Uruguay** has, in 2010, introduced the first net-metering regulation in South America. **Peru's** energy regulator (OSINERGMIN) awarded 80 MW of grid- connected PV capacity in 2010 following a blind bidding procedure with a ceiling of 0,269 USD/kWh. Grid-connected PV is also being introduced in **Argentina**, **Chile** and **Columbia**.

Morroco has launched a 2 GW Solar Plan with a dedicated implementing agency; PV and CSP technologies are expected to compete openly in this context, and export of solar electricity to Europe is foreseen. In the **United Arab Emirates** the MASDAR initiative is moving ahead targeting an extensive deployment of PV, although the global economic crisis appears to have lead to a postponement of targets. **Saudi Arabia** is reported to have set a target of 5 GW of solar power inside a decade, and it appears the country aspires to export solar electricity to neighboring countries and international markets given the advances in low-loss electricity transmission. **Oman** has established a renewable energy strategy including PV and is presently – following international tenders – installing PV systems in support of the many diesel powered mini-grids in the country. **Egypt** has set a target of 20 % renewable energy by 2020, and both CSP and PV are expected to contribute to reaching this target. Both **Algeria** and **Jordan** are developing ambitious solar energy and PV plans.

South Africa is rolling out plans for a 5 GW solar park in Upington; however this is separate to the Department of Energy's Integrated Resource Plan 2 (IRP2010) on electricity planning up to 2030 that mentions a target of 600 MW of PV by 2019. The solar park at Upington is understood to be a mix of PV and CSP, but the actual sharing of technology is not known. In 2010 two PV farms of 2,5 MW and 5 MW were connected to the grid in the archipelago state of **Cape Verde** covering about 4 % of the national electricity consumption. **Uganda** has – probably as the first country in Africa – introduced a Renewable Energy Feed-in Tariff (REFIT) programme under the administration of the Electricity Regulatory Authority. The REFIT programme includes wind energy, geothermal energy, biogas and landfill gas and PV; for PV the tariff is 0,36 USD/kWh for 20 years.

1.4 R&D activities and funding

The public budgets for research and development in 2010 in the IEA PVPS countries are outlined in Table 4. Most countries have reported significant increases in expenditure in 2010 compared to 2009. It is interesting that despite discussion about rapidly approaching grid-parity, sustainable markets and PV now being regarded as a mainstream electricity supply option, governments are clearly identifying the benefits of further development of technology, better integration with existing energy systems and new innovations. The most significant of the reporting countries in terms of expenditure are the US, Germany, Korea, Japan, Australia and France. Norway, with an increasing R&D budget, is interesting because of the size of the country and the level of investment in R&D compared to 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 R&D sector in key countries is presented below.

The US is a clear leader in terms of R&D public funding for PV. DOE accelerates the research, development, and deployment of all solar energy technologies through its Solar Energy Technologies Programme (SETP). In 2010, SETP held workshops with industry and other stakeholders to develop a roadmap to reach the goal of 1 USD per watt installed price of utility-scale PV systems by 2020. Information from these workshops was used to develop the SunShot Initiative, whose main objective is to enable solar energy to achieve grid parity in the United States without subsidies by the end of the decade. To bridge the gap between basic and applied solar research, SETP in 2010 funded the third and final year of the Next Generation Programme projects—primarily at universities—to develop innovative and revolutionary PV approaches. In 2010, SETP also continued to fund domestic PV start-ups through its PV Incubator Programme for promising technologies that have been proven on a laboratory scale and are ready to transition to commercial production. Over the course of three years, Technology Pathway Partnerships projects have accelerated industry's progress in developing specific system approaches that address total PV system lifecycle costs. In 2010, SETP released a Funding Opportunity Announcement for 112,5 million USD for SunShot Advanced Manufacturing Partnerships to support the creation of a robust US PV manufacturing base and supply chain, develop a highly trained workforce with the required technical skills, and speed the implementation of new cutting-edge technologies. In 2010, SETP's Solar Energy Grid Integration Systems (SEGIS) project advanced into its third and final stage, with 9,2 million USD of funding for demonstration of inverters with advanced functionality and communications to enable high grid-penetration levels for PV systems.

In Germany, R&D is conducted under the 5th Federal Programme on Energy Research and Energy Technology entitled Innovation and New Energy Technologies. Within this framework, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) as well as the Federal Ministry of Education and Research (BMBF) support R&D ranging from basic research to applied research on almost all aspects of PV. In 2010, BMU and BMBF initiated the Innovation Alliance PV. Under this scheme R&D projects will be funded which support a significant reduction of PV production costs in order to enhance the competitiveness of Germany's industry. Projects under industrial leadership integrating different steps of the PV value chain are sought, and cooperation between PV industry and PV equipment suppliers is encouraged. BMU and BMBF support this initiative with funding of 100 million EUR. The German PV industry agreed to raise an additional 500 million EUR and the first R&D projects were scheduled for the beginning of 2011.

From 2008, Korea Energy Technology Evaluation and Planning (KETEP) assumed the lead role in Korea's PV R&D programme. The R&D budget tripled in 2008 compared to 2007, showed a 20 % increase in 2009 and a further 12 % increase in 2010. In 2010, 25 projects were initiated and 59 projects continued under the five R&D sub-programmes: Strategic R&D, Basic & Innovative R&D, Core Technologies Development, Demonstration and International Joint Research. The R&D budget for the 25 new projects amounted to 27,5 billion KRW.

During 2010 in Japan, R&D of High Performance PV Generation System for the Future commenced as a five-year R&D programme with the aim of facilitating the 28 GW 2020 target for PV power installation set by the Japanese government. In addition the Research and Development on Innovative Solar Cells (International Research Center for Innovative Solar Cell Programme), operating since 2008, underwent mid-term evaluation and discussion of its direction out to 2014. In the field of fundamental research, Development of Organic Photovoltaics toward a Low-Carbon Society has been conducted by the University of Tokyo since 2009. The Ministry of Education, Culture, Sports, Science and Technology (MEXT) implements two programmes, Photoenergy Conversion Systems and Materials for the Next Generation Solar Cells, and Creative Research for Clean Energy Generation using Solar Energy. Major demonstration research projects implemented in 2010 were: Verification of Grid Stabilization with Large-scale PV Power Generation Systems, Development of an Electric Energy Storage System for Grid-connection with New Energy Resources, Verification Test of a Microgrid System for Remote Islands, Demonstration of Next-Generation Energy and Social Systems, International Cooperative Demonstration Project for Streamlining of Energy Consumption (Japan-U.S. Smart Grid), International Cooperative Demonstration Project for Stabilized and Advanced Grid-connection PV System, and International Cooperative Demonstration Project Utilizing Photovoltaic Power Generation Systems.

The Australian Solar Institute (ASI) has a primary role of investing in research & development projects that will accelerate innovation in photovoltaic and concentrating solar thermal technologies. The Australian Centre for Renewable Energy (ACRE) was established in 2010 with the aims of delivering programmes and providing relevant policy advice to move promising renewable energy technologies, products and services through their innovation cycles to commercial competitiveness. For PV, ACRE's priority will be on enabling technologies, including storage, grid connection technologies and hybrid systems. The Australian National University's Centre for Sustainable Energy Systems (CSES) is one of the largest and longest established solar energy research groups in Australia. The PV devices group at Murdoch University is continuing its research on new device designs based on amorphous and nanocrystalline silicon. The University of Queensland has a broad portfolio of solar PV research, as does the University of NSW. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) Energy Centre in Newcastle is home to the National Solar Energy Centre, a suite of research capability in both solar thermal and photovoltaics technologies and conducts projects aligned with Australia's national research priorities. The Victorian Organic Solar Cell Consortium (VICOSC) brings together over 40 researchers from the University of Melbourne, Monash University and CSIRO's Future Manufacturing Flagship.
The Agence de l'Environnement et de la Maîtrise de l'Énergie (the French Agency for the Environment and Energy Management), ADEME, is the organisation which has historically funded development and promotional activities in PV in France. The National Research Agency (ANR) deals with upstream research and development on a pre-manufacturing level while ADEME supports technological development in industry targeted at placing new commercial products in the market. Research in the PV sector is principally led by the French National Solar Energy Research Institute (Institut National de l'Energie Solaire – INES), INES, and the Photovoltaic Energy Research and Development Institute (Institut de Recherche et Développement sur l'Energie Photovoltaïque), IRDEP, plus twenty or so teams from the National Scientific Research Centre (Centre National de la Recherche Scientifique), CNRS, which are based throughout the country. The INES research programme in the PV field focuses on cells, modules, systems and storage. Another major R&D programme is the POLYSIL project which is focused on the industrial development of thin-film photovoltaic technology.

Whereas there are no public funds made available for PV market stimulation in Norway, government PV funding, primarily for R&D, amounted to 144 million NOK in 2010 (up from 91 million NOK in 2009, 56 million NOK in 2008, 37 million NOK in 2007 and 14 million NOK in 2006). Further it is estimated that industry provided funding of about 50 million NOK for these projects. It is also estimated that the in-house financing of research on proprietary technology by the industry could have been at least 50 million NOK during 2010. The Norwegian Research Council (NRC) is the government body that has the responsibility for managing and organizing all the public funds for R&D. Research activities on PV in Norway are focused on issues relating to silicon feedstock for crystalline cells, and wafer and cell production technologies. Minor activities deal with system integration issues.

2010 marked the fourth year of the European Union's 7th Framework Programme which will operate until 2013. FP7 has a significantly increased budget compared to the previous framework programme. Material development for longer-term applications, concentration PV and manufacturing process development have attracted most European funding in FP7. Significant funding has also been made available for thin-film technology.

Table 4 – Public budgets for R&D in 2010 in selected IEA PVPS countries

Country	Million EUR	Million USD
AUS	43,8	57,6
AUT	5,2 (2009)	6,8 (2009)
CAN	10,9	14,4
DEU	>64	>84
DNK	3,4	4,4
ESP	13	17,1
FRA	43,5	57,2
ISR	0,4	0,53
ITA	5,8	7,6
JPN (METI)	51,8	68,1
KOR	55,2	72,6
MEX	0,5	0,6
NOR	18,1	23,8
SWE	6,3	8,3
USA	131,0	172,4

2 The PV Industry

This section provides a brief overview of 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 2010. The reader is directed to the relevant national survey report for a more detailed account of PV production in each member country.

A national overview of PV material production and cell and module manufacturing in the IEA PVPS countries during 2010 is presented in Table 5 and is directly based on the information provided in the national survey reports. IEA PVPS does not undertake direct assessment of production developments in countries not participating in the IEA PVPS Programme. Industry analyses are routinely undertaken by industry associations such as EPIA and others.

The addition of China to the list of PVPS member countries in 2010 has made a significant difference to the data collected. Including China the PVPS member countries produced 17,6 GW of PV cells which likely account for around three-quarters of the worldwide production of PV cells. However if China is excluded the other countries account for around one-third, down from about one half of the worldwide production in 2009 and 2008, approximately two-thirds in 2007, about three-quarters in 2006 and at least 90 % previously.

The PV industry ranges from small specialized companies to large multinational vertically integrated companies with manufacturing facilities spread across a number of countries. An increasing number of companies are strengthening vertical integration with in-house manufacture of wafers for their own cell and module production. The trend to moving mass production to low labour cost countries, particularly in Asia, also continued in 2010.

Table 5 – Reported production of PV materials, cells and modules in 2010 in selected IEA PVPS countries

Country *(1)*	Solar PV Grade Si Feedstock production (tonnes)	Production of Ingots (tonnes)	Production of wafers (MW)	Cell Production (all types, MW)	*Cell production capacity (MW/year)*	Module production (MW) ***(2)***		
						wafer based (sc-Si & mc-Si)	thin film (a-Si & other)	*Module production capacity (MW/year)*
AUS	–	–	–	8	50	8	–	38
AUT	–	–	–	65	117	112	–	na
CAN	8 **(3)**	–	–	0,3	na	110	0,3	>506
CHE	–	900	120	>11	>40	12	>2,2	>40
CHN	45 000	na	na	9000	na	10 000 **(4)**	na	na
DEU	30 100	1200	1990	2700	3280	1800	660	3200
DNK	–	–	–	–	–	2	–	2
ESP	–	na	na	100	335	699	na	2004
FRA	Pilot **(5)**	680	70	na	71	na	na	525
ITA	na	–	–	>91	215	>305	–	495
JPN	6302	3795	669	2311	>2629	>1957	347	3545
KOR	20 000	na	800	770	1355	925	–	1890
MEX	–	–	–	60	–	172	60	275
MYS	–	–	–	na	1559	na	na	1182
NOR	<6000	na	1410	na	225	–	–	–
PRT	–	–	–	5,5	40	70	5,5	185
SWE	–	–	–	–	–	181	–	291
TUR	–	–	–	–	–	21	–	27
USA	42 561	na	624	1133	2112	798	467	2029

Notes:
(1) Although a number of IEA PVPS countries are reporting on production of feedstock, ingots and wafers, cells and modules, the picture from the national survey reports of the PV industry supply chain is by no means complete and consequently these data are provided more as background information.
(2) 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.
(3) Plus 350 metric tonnes Cadmium Telluride production that is exported for the fabrication of thin-film CdTe modules
(4) Figure includes both wafer based and thin film modules
(5) Pilot plant with 200t/yr capacity

Changes in the REC group of companies illustrate these trends. REC is a vertically integrated multi-national group, based in Norway. They are a major producer of polysilicon and wafers for solar applications, and a rapidly growing manufacturer of solar cells and modules. Their companies include: REC Silicon which produces solar grade silicon, and silane gas at plants in the USA; REC wafer which produces ingots and wafers at plants in Norway and Finland; and REC Cell which produces solar cells in Norway. A new facility REC Solar was opened November 2010 in Singapore to manufacturer wafers, cells and modules. REC ScanModule was their module production plant in Sweden, however it closed in 2010 and production moved to Singapore. Global cell production capacity increased dramatically during 2010 leading many commentators to warn of overcapacity in the market in 2011 particularly given the slowing of European markets. With plans announced continuing to increase manufacturing capacity in 2011 and beyond there are significant levels of overcapacity building up. These are expected to lead to increased competition and price pressures at all levels of the value chain.

Reductions in energy use during all stages of the manufacturing process continue with significant R&D efforts being devoted to further reductions. For example the PV industry in Germany is reported to be focusing their activities on process optimization to reduce the production cost and to increase the quality of their products.

Globally the manufacturing capacity for high efficiency modules such those based on Heterojunction with Intrinsic Thin layer (HIT) cells and back contact technologies is increasing. The Japanese company Sharp is beginning mass production of new single crystalline solar cells with production capacity of 200 MW/yr. The high conversion efficiency cells use a back contact structure (electrodes are connected on the back-side,) which eliminates the need for electrodes to be set on the front-side. This new structure increases the light-receiving area on the front-side's surface. The Austrian company AT&S installed a 40 MW automated manufacturing line for conductive backsheet foils which they hope will be the base for every back contact technology module manufacturer.

Finally requirements for local content in PV systems installed under programmes in Ontario, Canada, Italy and in the USA due to the Buy America policy also influenced manufacturing plans in these countries. A number of new PV module manufacturers are reported to have established a presence in Ontario stimulated by the Feed-in Tariff and its Ontario content requirement.

2.1 Feedstock, ingots and wafers (upstream products)

Crystalline silicon wafers remain the dominant substrate technology for making PV cells and the discussion in this section mainly focuses on the wafer-based production pathway. Although most 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

Silicon feedstock production requires large and expensive processing plants. As a consequence its production has been concentrated in a relatively small number of countries. It is an international business, with the product sold internationally and companies owned by multi-national organizations. In 2010 solar photovoltaic grade silicon feedstock supply was dominated by China, Germany, Japan, Korea and the US, with smaller levels of production in Canada, Italy and Norway. Together they produced around 150 000 tonnes. Most of these countries are net exporters of polysilicon, apart from Japan and China. China produced 45 000 tonnes of polysilicon, however Chinese companies consumed 89 000 tones of polysilicon, nearly 50 % of which was imported, a significant drop from the 92,5 % imported in 2006.

Production levels increased most rapidly in China and Korea, where production more than doubled. In China there are more than 15 companies manufacturing feedstocks and many more aspiring producers. However the government has set policy guidelines for new polysilicon projects. These require a capacity of at least 3 000 tonnes per year and a power consumption for solar-grade polysilicon lower than 60 kWh/kg as well as minimum recycling rates for gases used. In addition, all capacity with power consumption above 200 kWh/kg is scheduled to be closed by 2011.

Korea is also building up a significant feedstock industry. Two companies started production in 2010 while the third and largest company, OCI, expanded its manufacturing capacity to 27 000 tonnes/year. Together they produced a total of 20 000 tonnes in 2010. Additional manufacturers are planning to enter polysilicon manufacturing, supported by the Korean government. The more established producers in Germany, Japan and the US also increased production albeit at slower rates.

New feedstock facilities are planned including plants in Spain, France and Italy. In Malaysia the Japanese company Tokuyama is constructing a 6 000 t/yr plant in Sarawak which is planned to start operation in 2011. Outside of the PVPS countries silicon feedstock is also produced in India and Qatar, with plans for new production facilities in Brazil, Taiwan and the UAE.

Many manufacturers are investing in R&D relating to more efficient manufacturing processes. 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 and are working on replacing the current expensive and energy intensive purification process, based on chemical vapour deposition (CVD), by cheaper more energy efficient alternatives including metallurgical purification (condensed phase). In France the Spanish company Ferropen is collaborating with the INES research institute on a pilot facility with a capacity of 200 tonnes/yr. The process involves the removal of impurities using a plasma torch and the aim is to reduce costs to 33 USD/kg, compared to the 2010 spot price of USD 80–90/kg.

Manufacturing capacities are also reported as growing for feedstocks for other PV technologies. In Canada 350 tonnes of CdTe high purity compounds were produced in 2010 as feedstocks for cadmium telluride based PV cells. In Japan manufacturers are responding to the growing demand for monosilane gas for thin-film silicon PV modules, Mitsui Chemicals and Tokuyama are now collaborating on manufacturing technology development and Evonik Degussa is planning to construct a monosilane gas plant which is expected to start operation in 2011.

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.

China, Germany, Japan, Korea and Norway are the dominant producers in this section of the value chain with additional manufacturing capacity in Switzerland, France and the USA. The global production capacity for wafers is estimated to be 30–35 GW, more than 55 % of which is in China. In Japan an increasing number of companies are strengthening their production capacities or newly entering manufacturing of ingots and wafers due to the dramatic expansion in the global demand for solar cells. Ishii Hyoki, TKX, Osaka Fuji Corporation, Nakamura Choko, Kitagawa Seiki and others are strengthening their production.

Norway has a large manufacturing capacity for ingots and wafers with two manufacturing companies REC Wafer and NorSun AS. REC Wafer produces both monocrystalline ingots and wafers and multicrystalline ingots and wafers. Their targeted production for 2011 in Norway is 1 650 MW. In addition wafers are produced in Singapore at REC Solar's integrated production facility for wafers, cells and modules. REC's wafer capacities, including Singapore, total approximately 2,4 GW. NorSun AS manufactures monocrystalline silicon ingots and wafers. Their Norwegian plant has an annual production capacity of approximately 200 MWp. They also operate a facility in Vantaa, Finland in cooperation with Okmetic, with a current production capacity over 30 MWp per year. The company has a third production facility under construction in Singapore, which is expected to have a capacity of 500 MWp in 2013.

In the United States wafer manufacturing increased 97 %, from 317 MW in 2009 to 624 MW in 2010. There are four companies engaged in wafer manufacturing: Solar World America, Evergreen Solar, Solar Power Industries, and MEMC Electronics. All but MEMC Electronics are vertically integrated companies, with a large proportion of wafer production directed to cell manufacturing.

2.2 Photovoltaic cell and module production

Total PV cell production for 2010 in the IEA PVPS countries is estimated to be 17,6 GW. China was the lead producer of PV cells in 2010 manufacturing around 9 GW of cells. This was more than double the 4 GW of cells estimated to be manufactured in China in 2009. Other PVPS countries manufacturing at the GW scale in 2010 include Germany with 2,7 GW, Japan with 2,3 GW and the US with 1,1 GW. These four countries together account for 87 % of the cell production in PVPS countries.

If China is excluded from the figures total cell production in the IEA PVPS countries was about 8,6 GW, up from 6 GW in 2009, an increase of 43 %. Germany's production steadied at 2,7 GW, an increase of 10 %, down from the dramatic 62 % increase of the previous year while Japan's production ramped up by 55 %. Other countries which reported significant increases in cell production were Austria, Spain and Korea.

Global PV cell production is estimated at 23 GW to 24 GW. The IEA PVPS countries account for around 75 % of this global production. Taiwan (a non-PVPS country) has a major cell manufacturing industry with a capacity of around 5,3 GW.

The picture for PV module production is similar to that for cell production with 20,4 GW of wafer based and thin film modules produced in the IEA PVPS countries. Again the largest producers were China producing 10 GW, Germany 2,4 GW, Japan 2,7 GW and the USA with 1,3 GW. Other countries with over 500 MW of production were Spain, Korea and Malaysia. In total the PVPS countries produced over 18 GW of wafer based modules and 2,4 GW of thin film modules.

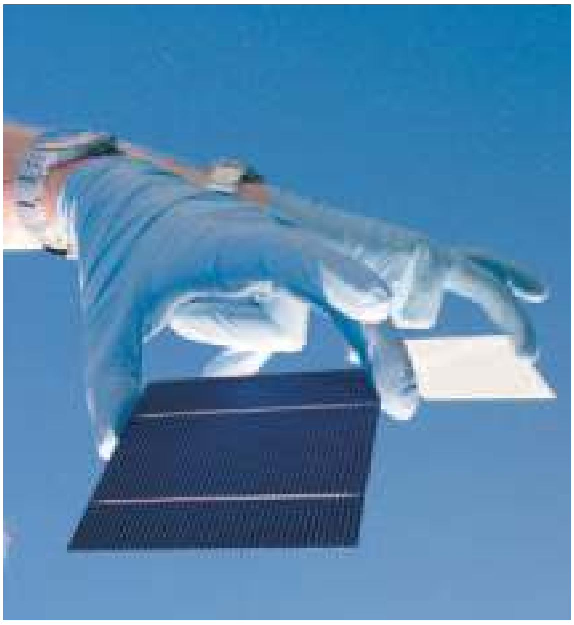
Crystalline silicon accounted for 88 % of the modules produced in 2010. This is a higher proportion than in the previous three years when the proportion of crystalline silicon modules had been dropping. The shift is because the vast majority of new production in 2010, particularly in Asia, was crystalline silicon.

Thin film accounted for 12 % of module production in IEA PVPS countries in 2010. Thin film module manufacturing is concentrated in a smaller number of countries; Switzerland, Germany, Japan, Malaysia, Mexico and the USA have a significant proportion of their manufacturing devoted to thin film modules. Labour costs are relatively high in some of these countries but thin films are less labour intensive than crystalline silicon modules and require a skilled workforce to maintain high efficiencies and production yields. USA based companies are very strong in thin film and are increasing production capacity in other locations as well as the USA. Unisolar manufacture thin film silicon modules in Mexico and First Solar produce cadmium telluride thin film PV modules in Malaysia. In 2010 First Solar's annual production capacity was 954 MW with plans to ramp up capacity to 1 430 MW in 2011.

Total IEA PVPS country module production increased by 57 % in 2010: if China is again left out of the calculation. This compares to over 60 % the previous year, following growth of about 50 % in each of the previous two years. In Germany module production declined slightly, while in Japan module production more than doubled and in the USA module production increased by 63 %. Spain's module production bounced back strongly increasing by 160 % after almost halving between 2008 and 2009. Significant module production increases were also reported in Austria, Canada, Switzerland, France, Italy, Korea and Mexico.

In 2010 14,2 GW of PV were installed in the IEA PVPS countries. This accounts for 71 % of the modules produced in these countries, including China, and 137 % excluding China. This compares to 95 % in 2009 and over 150 % in 2008. It had previously ranged from 59 % to 91 %.

The module production capacity in the IEA PVPS countries (excluding China), increased by over 6 GW in 2010 to 16,4 GW. This was a record increase, easily surpassing the previous record in 2009 of



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3,6 GW increased capacity. The utilization of capacity was 62 %. The cell production capacity, again excluding China, was 12,2 GW and the utilization of capacity was 70 %.

Plans to further increase manufacturing capacity were reported by a number of countries. In Japan plans totaling a 45 % expansion in manufacturing capacity in 2011 were announced, while longer term plans would double the manufacturing capacity in Japan. Japanese owned companies also have plans to increase capacity in other manufacturing locations. Sharp plan to increase the production capacity of their UK plant from 250 MW to 500 MW by February 2011. Kyocera have a manufacturing facility under construction in the Czech Republic and are expanding their manufacturing plant in China. Sanyo are expanding their module manufacturing capabilities in Hungary by 135 MW.

Malaysia has ambitious aims to become one of the top world producers of solar products. In 2010 five PV manufacturers were operating, three international manufacturers and two local companies. The internationals are First Solar, Q-Cells and Flextronics Technology. Flextronics assemble PV modules made from solar cells by Q-Cell which are shipped back to Q-Cells. The local PV manufacturers are SolarTIF Sdn Bhd and Malaysian Solar Resource (MSR) Sdn Bhd. A third Malaysian company, AUOSunPower, was officially launched by the Prime Minister of Malaysia in December 2010.

A number of countries, particularly in Europe, have responded to the tendency to move production to

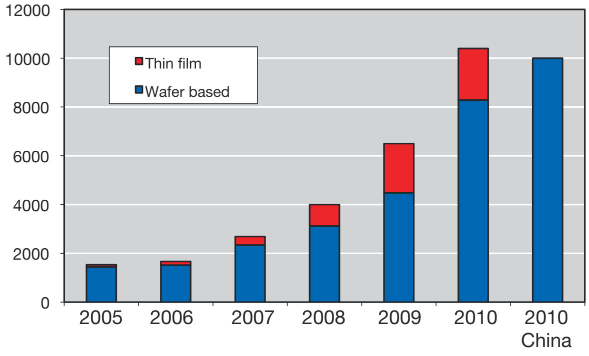

Figure 4 – Trends in photovoltaic module technologies in the IEA PVPS countries 2005–2010

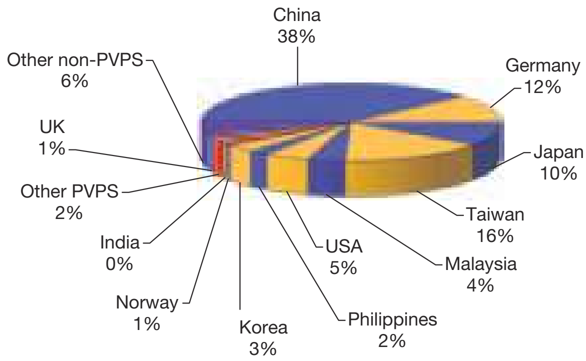

Figure 5 – Estimated world PV cell production (%) by country in 2010

Asia by focusing on specialized areas such as products designed for building integrated PV (BIPV) or on the development of new products.

In Austria there are seven domestic module manufacturers who reported production in 2010 of 112 MW, a growth of 83 % compared to the previous year. A number of these companies focus on the BIPV market producing laminated safety glass modules, PV-roof tiles and small size modules for BIPV applications. Glassless flexible PV laminates specifically designed for noise barrier walls are also produced. Most of the modules produced use imported cells and virtually the whole production is exported. One company Crystalsol is developing a thin film flexible photovoltaic module; their first product will be a low cost semi-finished photovoltaic film for the building integration market.

In France strong efforts are being made to increase local manufacturing with significant investments in both R&D and manufacturing. The manufacturing capacity for crystalline silicon modules rose to 525 MW in 2010 from just over 200 MW in 2009. Projects are also being developed using CIGS and CdTe technologies. The INES research organization in association with Korean equipment manufacturer Jusung is working on the development of high performance heterojunction cells, aiming at a 25 MW capacity plant in two years time.

In Sweden the polycrystalline module manufacturer PV Enterprise Sweden AB responded to the increased competition from Asian countries and the declining interest for modules produced in Europe by deciding to focus production in Sweden on designed and tailored solutions for BIPV while the production of standard modules is handled by partners in China. Although the company increased its total production in 2010 with the agreements in China, the production in Sweden decreased due to the new strategy to produce smaller batches with specially designed modules. Various companies are also conducting R & D on specialized products including two companies working on CIGS, three companies working on products that combine low concentrating PV and solar thermal power generation, a company working on dye-sensitized solar cells and another looking at high efficiency nanowire solar cells for concentrating PV systems.

In Switzerland there are a few companies with limited production serving mainly the niche market of BIPV. However there is considerable R&D on-gong and strong global demand is helping companies focused on BOS components such as Multi Contact (junction boxes, connectors), Huber & Suhner (cables, connectors) and Sputnik Engineering (inverters).

Modules and cells are also manufactured outside the IEA PVPS countries. Taiwan is home to a booming PV industry supplying a significant share of global cell production. 15 to 20 companies have an estimated cell production capacity of around 5,3 GW and a similar number of companies have a module production capacity of about 1,2 GW; wafer production capacity is estimated at 2,2 GW. The PV industry in Taiwan is thus concentrated around the high value part of the value chain.

In the Czech Republic 550 MW of modules were produced in 2010, of which 300 MW were made by German-owned company Schott Solar, 150 MW were from the Japanese company Kyocera, and the remainder were produced by local companies. The majority of modules are exported.

In Brazil module manufacturing is declining with only one pilot plant active in 2010. The Indian PV industry includes large scale companies such as Moser Baer and Tata BP Solar. The annual production capacity of PV modules in India is estimated at around 1 GW to

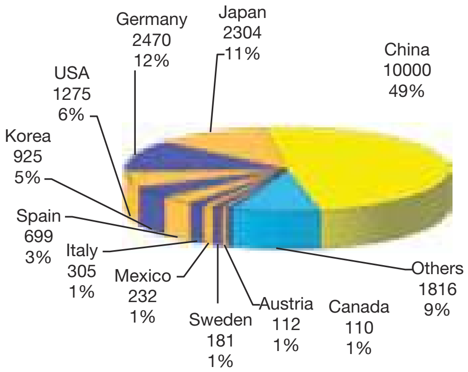

Figure 6 – PV module production (MW) by country in 2010

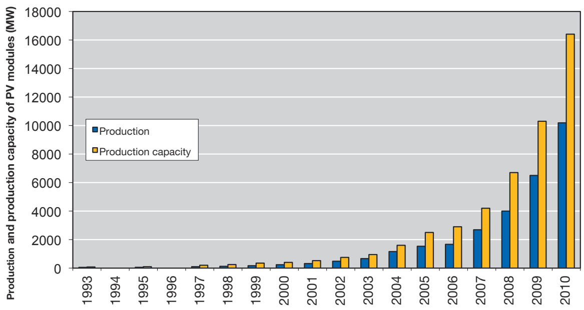

Figure 7 – Yearly PV module production and production capacity in the IEA PVPS reporting countries

1,2 GW. However, it is very difficult to find consensus among international estimates except for the pure number of cell and module manufacturers.

In Thailand about five companies produce PV modules with an estimated total capacity of 130 MW and in South Africa the French owned company Tenesol has a module manufacturing plant with a capacity of 85 MW.

Concentrating photovoltaic systems are also starting to be commercially produced although the quantities are still relatively low. Around 10 MW of CPV cells were manufactured by Concentrix Solar in Germany. In the USA 35 MW of cells were manufactured by Spectrolab and Emcore and 10 MW of CPV modules by Amonix. Trial plants are in operation in Australia and France.

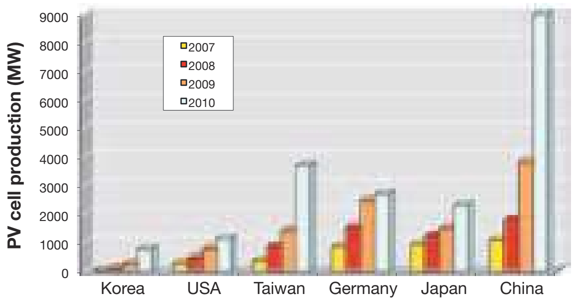

Figure 8 – Evolution of the PV industry in selected countries – cell production 2007, 2008, 2009 and 2010

2.3 Balance of system component manufacturers and suppliers

Balance of system (BOS) component manufacture and supply is an important part of the PV system value chain and is accounting for an increasing portion of system costs as PV module prices fall. Accordingly the production of BOS products has become an important sector of the overall PV industry.

With the installation of so many grid-connected PV systems, inverter technology is currently the main focus of interest. With new grid codes requiring the active contribution of PV inverters to grid management, new inverters are currently being developed with sophisticated control and communications features. With the help of these functions, the PV plants can actively support grid management, for example by providing reactive power or back-up capacity.

In Europe the large PV inverter companies are located in Germany, Spain, Austria, Switzerland, Denmark and Italy. Outside Europe, activities in this field are reported from Japan, the US, Korea and China. New market players and increased production have been reported from non-PVPS countries, particularly Taiwan, supporting the trend towards a further price reduction of the products. However, ongoing high levels of demand resulted in inverter supply shortages world-wide and caused installation delays for many systems during 2010.
The products dedicated to the residential PV market have typical rated capacities ranging from 1 kW to 10 kW, and single (Europe) or split phase (America, Japan) grid-connection. For larger systems, PV inverters are usually installed in a 3 phase configuration with typical sizes of 10 kW, 30 kW and 100 kW. With the increasing number of utility-scale PV systems in the MW range, larger inverters have been developed with rated capacities up to 2 MW.

Production of specialized components, such as PV connectors, DC switchgear and monitoring systems, is an important business for a number of large electric equipment manufacturers. Dedicated products and solutions are now also available in the utility-scale power range.

2.4 System prices

Reported prices for entire PV systems vary widely (Table 6) and depend on a variety of factors including system size, location, customer type, connection to an electricity grid, technical specification and the extent to which end-user prices reflect the real costs of all the components. For more detailed information, the reader is directed to each country's national survey report.

On average, system prices for the lowest price off-grid applications are 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 2010 the lowest system prices in the off-grid sector, irrespective of the type of application, typically ranged from about 5,5 USD/W to 8 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 8 USD/W, about 20 % less than the corresponding average price reported for 2009.

The lowest achievable installed price of grid-connected systems in 2010 also varied between countries as shown in Table 6. The average price of these systems was 4,2 USD/W, about 13 % lower than the average 2009 price. Prices as low as just over 3 USD/W were reported; typically prices were in the range 3,2 USD/W to 4,9 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.

Table 6 – Indicative installed system prices in reporting countries in 2010

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	**4,2–10,5**	5,5–13,8	**4,9–13,9**	6,4–18,3	**3,5–4,9**	4,6–6,4	**4,2–6,3**	5,5–8,3
AUT	**4–9,1**	5,3–12,0	**4–9,1**	5,3–12,0	**3,2–4,2**	4,2–5,5	**2,4–4,1**	3,2–5,4
CAN	**12,2**	16,0			**4,8–5,9**	6,3–7,8	**3,0**	3,9
CHE					**3,9–5,3**	5,5–7,0	**3,3–4,1**	4,4–5,4
DEU					**2,6–3,2**	3,4–4,2	**2,3–2,5**	3,0–3,3
DNK	**4,0–6,8**	5,3–8,9	**8,1–13,5**	10,7–17,8	**2,7–4,0**	3,6–5,3	**2,7–5,4**	3,6–7,1
ESP					**2,5–3,1**	3,3–4,1	**2,4–2,7**	3,2–3,6
FRA	**6–10**	7,9–13,2			**4,8–5,9**	6,3–7,8	**3,5–5,5**	4,6–7,2
ISR					**2,4–6,6**	3,2–8,7	**2,9**	3,8
ITA	**6–8**	7,9–10,5			**3,5–4,1**	4,6–5,4	**2,8–3,5**	3,7–4,6
JPN					**5,0**	6,6	**5,3**	7,0
KOR					**3,3**	4,4	**2,8**	3,7
MEX	**5,4**	7,1	**7,4**	9,8	**4,9**	6,4	**7,5**	9,8
MYS					**3,7**	4,9	**3,7**	4,9
NOR	**11,3–15,0**	14,9–19,8			**7,5–10,0**	9,9–13,2		
PRT	**8**	10,5			**4,5**	5,9	**3–4**	3,9–5,3
SWE	**7,4**	9,7	**6,3**	8,3	**4,8**	6,3	**3,7**	4,9
TUR	**4,5–5,5**	5,9–7,2	**4–4,5**	5,3–5,9	**2,5–3,5**	3,3–4,6	**2,5**	3,3
USA					**5,1**	6,7	**3,2–4,5**	4,2–5,9

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 2001–2010 (Normalized to 2001)

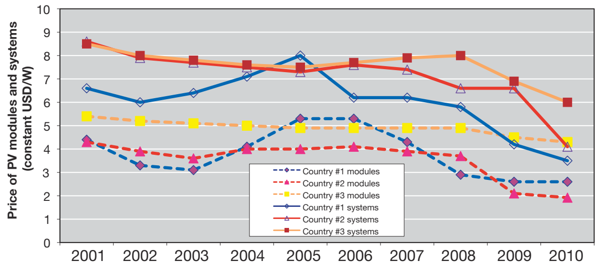

Figure 10 – Evolution of price of PV modules and small-scale systems in selected reporting countries accounting for inflation effects – Years 2001–2010 (2010 USD)

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

Country	Currency	2010 national currency	2010 EUR	2010 USD
AUS	AUD	2–3,2	1,4–2,2	1,8–2,9
AUT	EUR	1,8–5,5	1,8–5,5	2,4–7,2
CAN	CAD	2,27	1,7	2,2
CHE	CHF	2,2–3,6	1,6–2,7	2,1–3,5
DEU	EUR	2–3,6	2–3,6	2,6–4,7
DNK	DKK	10 -20	1,4–2,7	1,8–3,6
ESP	EUR	1,4–2	1,4–2	1,8–2,6
FRA	EUR	2	2	2,6
ISR	NIS	6,16	1,3	1,7
ITA	EUR	1,2–1,5	1,2–1,5	1,6–2,0
JPN	JPY	375	3,2	4,3
KOR	KRW	2000 –2400	1,3–1,6	1,7–2,1
MEX	MXP	28,47–43,33	1,7–2,6	2,3–3,4
MYS			0,9–1,2	1,15–1,57
PRT	EUR	1,5	1,5	2,0
SWE	SEK	20–27	2,1–2,9	2,8–3,8
TUR	TRY	3,0–5,0	1,5–2,5	2,0–3,3
USA	USD	1,92	1,46	1,92

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.

On average, the cost of the PV modules in 2010 (shown in Table 7) accounted for exactly 50 % of the lowest achievable prices that have been reported for grid-connected systems. In 2010 the average price of modules in the reporting countries was about 2,1 USD/W, a decrease of almost 20 % compared to the corresponding figure for 2009, following a decrease of 35 % the previous year. Most but not all reporting countries recorded lower module prices than in 2009. Eight countries reported module prices less than 2 USD/W; two thirds of the lowest achievable prices fell within the range of 1,8 USD/W to 2,6 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 2010 – for example, manufacturing equipment from Switzerland, silicon feedstock from the US, upstream material and PV cells from Norway, cells from Japan and the US, thin film from Malaysia and PV modules

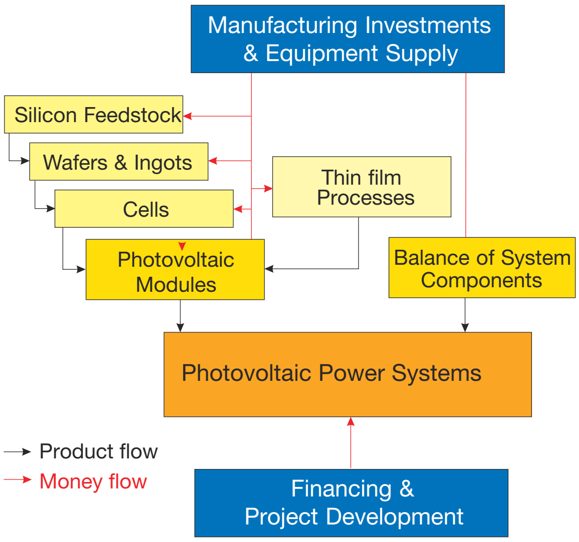

Figure 11 – Photovoltaic (PV) industry supply chain

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

Country	Research, development, manufacturing and deployment labour places
AUS	9 400
AUT	4 414
CAN	5 440
CHE	10 000
DEU	133 000
ESP	25 000
FRA	24 300
ITA	50 000
JPN	41 300
KOR	11 300
MEX	146
MYS	6 996
NOR	1 950
SWE	740
TUR	415
USA	102 496

from Austria, Spain, Japan, Korea, Mexico, Sweden and the US. With a massive industry and domestic market Germany trades extensively across the whole PV value chain. The total value of business in 2010 amongst the IEA PVPS countries approached 60 billion USD, double the figure for the previous year. This is because the annual market had increased considerably.

In parallel with the business value of PV production and markets, the economic value in the 16 IEA PVPS countries presented in Table 8 can be characterized by the total direct employment approaching 430 000 persons across research, manufacturing, development and installation, with steady annual increases in the reporting countries. The figures reported for 2010 are more than double the 2009 figure, after taking account of the Spanish job losses in that year. The strong market growth in an increasing number of countries (see Table 3 for example) means that the risks to business of relying on single markets have diminished. At the same time, new business risks are clearly emerging with the growth of global manufacturing competition. This presents a delicate balancing act for politicians seeking to boost domestic employment numbers in the renewable energy sector by encouraging rapid PV market growth.

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 2010 can be found in Table 9. A brief description of these measures can be found in section 1.3 of this report and further details are available in the relevant national survey reports, available from the IEA PVPS website. A brief outline of the measures is given in the following box.

Nearly all countries now offer or are planning feed-in tariffs for PV electricity. In fact the debate has now shifted from if or how to implement a feed-in tariff to how to move to the self-sustaining market post feed-in tariff. FiT approaches have successfully driven grid-connected PV investments in large-scale (multi-MW) plants, smaller-scale building-integrated applications and combinations of both. The FiT can be national-scale, state-based or even operate at the local community or utility level. They have been clearly seen as the prime mechanism for promoting strong growth in grid-connected PV applications.

Together with the upsides, FiTs that have been poorly designed or poorly controlled have resulted in explosive markets, profiteering, political interference, over-reliance on imports, market collapses, business closures and so on. Nearly every country has some sort of tale to tell in this regard. There is now a wealth of information available worldwide to policymakers regarding the impacts of various designs of feed-in

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

tariff schemes – the effects of differentiating tariffs according to various PV applications (BIPV, large ground-mounted plants and so on), the boundary effects of introducing caps on FiT schemes, the impact of whether payment is for all PV electricity generated or only the portion exported to the grid, and how and when to adjust tariffs to avoid overheated markets and windfall-seeking investors.

The salutary lesson is that while this support measure does appear neat and simple on the surface, it does take a lot of effort to firstly get it correct, and secondly to keep it functioning as desired in a very dynamic PV market. Probably one of the key messages from the successful German FiT experience – and this scheme also has had its share of critics – is not that it must be copied everywhere as is the popular perception, but just how much effort is involved to develop reasonable boundary conditions and operational parameters.

Table 10 provides a broad overview of some of the key PV support measures. In practice, public support often involves a combination of measures. There are many different combinations operating in the various countries – FiTs and capital subsidies, FiTs and tax credits, building regulations and subsidies, regulation and support activities, and so on. While fewer measures are likely to incur a lower administrative

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

	AUS	AUT	CAN	CHE	DNK	DEU	ESP	FRA	ISR	ITA	JPN	KOR	MEX	MYS	NLD	NOR	PRT	SWE	TUR	USA
Enhanced feed-in tariffs[1.] USD cents/kWh	55g, 55n	50	77,9	38,7–71,0g		37,82–51,5 [5.]	42,4	76,3	+	45,5–61,9	54,7n	+			+		+	+[2.]		+
Direct capital subsidies	+	+		+		+		+		+	+	+		+	+			+		+
Green electricity schemes	+	+	+	+		+	+			+	+									+
PV-specific green electricity schemes		+		+											+					+
Renewable portfolio standards (RPS)	+										+	+[3.]						+		+
PV special treatment, in RPS	+										+									+
Investment funds / finance schemes for PV			+			+	+					+								+
Tax credits			+	+				+			+			+	+		+			+
Net metering / net billing	+	+	+	+	+	+				+			+	+	+					+
Commercial bank activities	+					+			+		+				+		+		+	+
Electricity utility activities	+		+	+	+	+	+				+							+		+
Sustainable building requirements	+		+	+	+	+	+					+			+		+		+	
Indicative household retail electricity price [4.] USD cents/kWh	11,9–21,1	23,7	7	15,4	35,6	31,6			12,8	22,4	20,4–27,5	13,3–19,6	9	up to 14	28,8	11,6–14,9		23,6	17,5 w/o tax	11,58

Notes:
1. *Highest feed-in tariff offered in 2010 in USD cents/kWh; where indicated g=gross scheme, n=net scheme*
2. *Local, community-based scheme*
3. *Demonstration programme*
4. *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*
5. *During 2010 FiTs have been amended from 51,5 USD cents/kWh, to 44,8 USD cents/kWh on 1 July, to 43,46 USD cents/kWh on 1 October, to 37,82 USD cents/kWh on 1 January 2011*

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.

PV technology can now be regarded as mainstream in many of the countries with expanding PV markets, and the main policy challenge is to decide how best to move towards true market transformation. Probably within the next decade the sustainable market will eventuate with the arrival of grid parity. The issue now is how to best manage the transition period leading to grid parity.

This may involve moving support policies away from handouts of public money (albeit collected from electricity consumers) to focus more on enabling strategies, appropriate regulation and development of innovative business models. Some of this is discussed in the next section.

In general, any public support measure should be evaluated against a number of criteria and the following points are particularly relevant to those countries newly embarking on the pathway of public support for PV: While outcomes have been achieved elsewhere are the local barriers to be addressed the same as those tackled in other markets? Is the local

Table 10 – Characteristics of some key support measures

<table>
<tr><th></th><th>Enhanced feed-in tariffs</th><th>Direct capital subsidies</th><th>Green electricity schemes</th><th>Renewable portfolio standards</th><th>Tax credits</th><th>Sustainable building requirements</th></tr>
<tr><td>Target audience</td><td>Grid-connected PV customers with business cash flow requirements e.g. housing developers, investors, commercial entities.</td><td>PV customers with limited access to capital e.g. households, small businesses, public organizations.</td><td>Residential and commercial electricity customers.</td><td>Liable parties, typically the electricity retailing businesses.</td><td>Any entity with a tax liability, such as salary earners and businesses. However, may not be relevant for many prime candidates for PV.</td><td>New building developments (residential and commercial); also properties for sale.</td></tr>
<tr><td>Countries reporting use of this support measure, or similar (see section 1.3)</td><td>Australia, Austria, Canada, Switzerland, Germany, Spain, France, Israel, Italy, Japan, Korea, Portugal, the Netherlands, Sweden, USA.</td><td>Australia, Austria, Switzerland, Germany, France, Italy, Japan, Korea, Malaysia, Sweden, USA.</td><td>Australia, Austria, Canada, Switzerland, Germany, Spain, Italy, Japan, USA.</td><td>Australia, Japan, Korea, Sweden, USA.</td><td>Canada, Switzerland, France, Japan, Malaysia, Portugal, USA.</td><td>Australia, Canada, Switzerland, Denmark, Germany, Spain, Korea, Portugal, Turkey.</td></tr>
<tr><td>Implemen-tation</td><td>Typically administered by the electricity industry billing entity.</td><td>Requires considerable public administrative support to handle applications, approvals and disbursements.</td><td>Commercial business operation of the electricity utility; some public administrative support for accreditation of projects.</td><td>Public administrative support via a regulatory body.</td><td>Administered by the existing taxation bodies.</td><td>Typically administered by the local building consent authority.</td></tr>
<tr><td rowspan="2">Economic and political considera-tions</td><td>Method of internalizing the externalities associated with traditional energy supply</td><td>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.</td><td rowspan="2">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.</td><td rowspan="2">Can be seen as a distortion in the functioning of the electricity market, especially if overly prescriptive.</td><td rowspan="2">Same benefits as the direct capital subsidies but without some of the negatives.</td><td rowspan="2">Appeal largely depends upon the degree to which property prices are impacted and the cultural acceptance of prescriptive approaches.</td></tr>
<tr><td colspan="2">There are varying political perceptions regarding the use of public funds or funds generated by the electricity industry.</td></tr>
</table>

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 and business 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.

The regulatory approach commonly referred to as the ‹renewable portfolio standard› (RPS) is a powerful policy tool to increase renewable energy deployment, particularly in more competitive electricity markets. A number of countries have seen the RPS approach as a more politically acceptable approach to climate change policy than carbon taxes or emissions trading schemes. Rather than simply encouraging the lowest direct cost renewable energy options for consideration, RPS can be developed to provide direct support for PV deployment. The most obvious example is the US where a number of PV-specific regulatory approaches, such as PV set-asides, have been developed. Other countries 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. Most interestingly, in Korea the RPS is seen as the logical successor to the feed-in tariff scheme in the period leading up to grid parity.

In addition, sustainable building regulations are an emerging force in a large number of countries. These include requirements on new building developments (residential and commercial) and also in some cases on properties for sale. PV may be included in a suite of options for reducing the building’s energy foot print, or specifically mandated as an inclusion in the building development. It is considered that this approach will significantly grow the commercial sector building PV market which has hitherto been under-represented in many PV markets.

Worldwide, electricity utilities are now investing in very large-scale PV plants or asking how they can benefit from meeting their customers’ interest in PV plants or PV electricity, often driven by government mandates and increasingly leading to the pursuit of business opportunities. Part of this development in the near to medium term is being integrated with an increased focus on more intelligent electricity networks, the need for a more widespread deployment of electricity storage technologies and new markets for electricity such as charging of electric vehicles. These issues provide benefits, opportunities and challenges for electricity utilities and regulators. A range of electricity utility PV activities are presented in the national reports, and an outline of these follows.

In the past, **Australian** electricity utilities were heavily involved in PV demonstration programmes through their own R&D arms. More recently, electricity utility interest has largely been driven by government programmes, such as the Solar Cities and, to a lesser extent, Smart Grids programmes. All electricity retailers are liable under the Renewable Energy Target and some have installed their own PV systems to contribute to meeting their liability. Some utilities have also established solar businesses and retail PV systems to their customers. An electricity utility has purchased concentrating solar PV power stations and operates them to provide power to isolated communities.

In **Canada**, some utilities have developed and implemented programmes that streamline net metering approaches and set out approved tariffs. The **Danish** transmission system operator, Energinet.dk, has for several years expressed interest in PV as a potential contributor to electricity supply and in support of the electric grid. The distribution utilities, most notably EnergiMidt, have also promoted the use of PV and since 2009 several distribution utilities have included PV technology in their portfolio of products. Most distribution utilities simply regard PV as a relevant standard product and some offer finance packages and payment via the electricity bill. Interestingly, in **Germany** where the regulations of the EEG are so successful in eliminating barriers and in stimulating private sector investment, the electricity utilities play a subordinate role. The **Israel** Electric Corporation (IEC) takes a mainly technical role in support of the government’s feed-in tariff, and has published a considerable amount of technical information for the public and for the installers.

In **Japan**, electricity utilities introduced the Green Power Fund in October 2000 to promote the dissemination of energy sources such as PV. Over the period 2001 to 2010 the fund supported PV installations at 1 568 places nationwide, with a total capacity of 27,6 MW, mainly at public facilities such as schools and hospitals. However, with the commencement of the government’s New PV Power Purchase Programme in late 2009 some utilities including Tokyo Electric Power Co., Inc. (TEPCO) have scrapped the voluntary Green Power Fund. Electricity utilities have also purchased the required amounts of electricity generated from new and renewable energy under the Renewable Portfolio Standard (RPS) Law. Looking ahead, electricity utilities have formulated plans to construct PV power plants located at 30 sites with a total capacity of 140 MW across the nation by 2020 and have also started introducing PV systems at their own facilities.

Six **Korean** electricity generation companies have signed the RPA (Renewable Portfolio Agreement) with the government in order to increase the share of renewable energy in electricity generation. From 2012, the RPS (Renewable Portfolio Standard) will replace the feed-in tariff scheme. Thirteen companies are planned to participate in the RPS, which should realize 1,2 GW installed capacity of PV by the end of 2016. A clear declaration of interest in PV technology has been sent by the **Mexican** national electricity utility in 2010 with the installation of a grid-connected system at the offices of the General Director, and planning for MW size PV system underway. In 2010, **Malaysia's** Tenaga Nasional Berhad (TNB) has issued a call for tender for a 5 MW PV power plant as a demonstration project. The interest from the electricity utility business in PV is rather low in **Sweden**, except for Sala-Heby Energi AB which offers a local feed-in tariff scheme for a local PV community

Electricity utility interest continues to increase dramatically in the **United States**, with the key drivers being policy – the federal tax credit (30 %) at the national level and Renewable Portfolio Standards at the state level. Four broad categories of utility solar business models have emerged in the US: utility ownership of assets, utility financing of assets, development of customer programmes, and utility purchase of solar output. *Utility ownership* of assets allows the utility to take advantage of the tax policy benefits and earn a rate of return on the asset (for investor-owned utilities), while providing control over planning, siting, operating, and maintaining the PV facilities. *Utility Financing of Solar Assets* is a PV business option for utilities that do not choose to own solar assets for tax, cost, regulatory, or competitive considerations. To be successful, regulators treat the financing and lost revenue costs associated with a solar project as assets, allowing the utility to earn a rate of return on ‹investment›. *Customer Programmes* are designed to increase access to solar energy by lowering costs, for both the utility and the customer, compared to a traditional customer-sited PV system. Community solar programmes involve a community or centralized 0,1 MW to 20 MW PV system and specific classes of participating customers to whom a proportional share of the output can be allocated, offsetting their electricity bill directly or by offer of a fixed-rate tariff that is competitive with retail rates or will be in the near future as electric prices increase. *Utility Purchase of Solar Output* is a business model often applied by publically owned utilities to create value to their communities through local solar development. Some publicly owned utilities have developed a feed-in tariff to purchase PV electricity.

Despite these exciting developments in many of the developed economies it is a sobering reality that one third of the world's population still does not have 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. With a steadily decreasing cost of PV technology (plus the deployment experiences gained worldwide), it is timely that PV should begin to play a significant role in meeting the electricity needs of 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 2010, 82 IEC International Standards and Technical Specifications (including versions in different languages) had been published covering a comprehensive range of issues. Currently 33 countries are active participants in TC 82 and a further 13 have observer status. Increased involvement has been reported from Asian countries.

The work on new and revised standards is carried out within six individual working groups (WG). Cross-cutting issues such as Rural Electrification or Batteries are handled by a Joint Working & Coordination Group (JWCG) of experts from different TCs.

During 2010 TC 82 has published the following new or revised IEC standards or Technical Specifications (TS):
- IEC 62 109–1 Edition 1.0 2010–04–28 Safety of power converters for use in photovoltaic power systems – Part 1: General requirements
- IEC/TS 62 257–7–1 Edition 2.0 2010–09–29 Recommendations for small renewable energy and hybrid systems for rural electrification – Part 7–1: Generators – Photovoltaic generators
- IEC 62 509 Edition 1.0 2010–12–16 Battery charge controllers for photovoltaic systems – Performance and functioning

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 2010, one new European standard was published:
- EN 50 530:2010 Overall efficiency of grid connected photovoltaic inverters

Further issues at the top of CLC 82's list are the certification of building integrated photovoltaic modules and the harmonization of fire tests in Europe for photovoltaic components, especially photovoltaic modules.

In 2010, the US Department of Energy's OE PV programme continued to fund a significant level of involvement in the standards and codes area. The National Renewable Energy Laboratory (NREL) and Sandia National Laboratories (Sandia) staff served on panels establishing codes and standards for nearly every solar-related code or standard. The DOE-funded Solar ABCs (Solar America Board of Codes and Standards) completed its fourth year of activities focused on supporting the centralized development of codes and standards that facilitate and accelerate the installation of high-quality, safe photovoltaic (PV) systems. The United States paid particular attention to the IEEE and UL standards revisions that are required to accommodate high penetrations of distributed generation on the grid. These standards will need to be revised to allow inverters to provide the correct grid support characteristics when high penetrations of distributed resources are deployed.

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. As a complement to the current standards JET conducts a certification programme for the performance and reliability of PV system components.

Following the massive growth of grid-connected distributed PV and the increasing capacity of utility-scale PV systems, full integration of PV systems into grid operation is becoming vitally important. It has been widely acknowledged that without an active contribution of PV plants to grid management and ancillary services, further deployment of PV might be limited. For this purpose, new grid codes and interconnection guidelines have been or are being developed at the moment in a number of PVPS countries, particularly in those facing the largest capacity increases, for example Germany and the US.

4 *Summary of trends*

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

- About 14,2 GW of PV capacity were installed in the IEA PVPS countries (now including China) during 2010 – more than double the amount as in the previous year. This brought the cumulative installed capacity to almost 35 GW. By far the greatest proportion (69 %) was installed in Germany and Italy alone. If the US, Japan and France are also included, then over 87 % of PV installations in 2010 occurred in five countries. Continued dramatic growth of the annual grid-connected PV market worldwide was evident, with significant growth of the annual market in a number of the largest markets. Five countries rank in the GW cumulative installed PV capacity grouping. Germany's cumulative installed capacity grew at 74 % whereas Japan's growth rate approached 38 %. Cumulative installed capacity in the US increased at 57 %. Italy's cumulative installed capacity tripled, as did France's.

- With such dominance of the grid-connected markets (about 97 % of the cumulative installed PV capacity), off-grid markets tend to be ignored. This is unfortunate as these applications have the scope to dramatically change the lives of some of the world's most disadvantaged peoples. The market itself is healthy with sustained, solid growth over decades, and not subject to the same sort of political whims and flights of fancy as grid-connected PV. This market is also largely unsupported by public funding.

- Most countries have reported significant increases in R&D expenditure in 2010 compared to 2009. It is interesting that despite discussion about rapidly approaching grid-parity, sustainable markets and PV now being regarded as a mainstream electricity supply option, governments are clearly identifying the benefits of further development of technology, better integration with existing energy systems and new innovations. The most significant of the reporting countries in terms of expenditure are the US, Germany, Korea, Japan, Australia and France.

- In 2010 solar photovoltaic grade silicon feedstock supply was dominated by China, Germany, Japan, Korea and the US, with smaller levels of production in Canada, Italy and Norway. Together they produced around 150 000 tonnes. Most of these countries are net exporters of polysilicon, apart from Japan and China. Production levels increased most rapidly in China and Korea, where production more than doubled.

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		103	
1993	94	21	33	22	127	23
1994	112	19	39	18	151	19
1995	132	18	49	26	181	20
1996	158	19	61	24	219	21
1997	187	19	94	54	281	28
1998	216	15	139	48	355	26
1999	244	13	227	63	471	33
2000	277	14	401	77	678	44
2001	319	15	647	61	966	42
2002	354	11	983	52	1 337	38
2003	410	16	1 408	43	1 818	36
2004	450	10	2 426	72	2 876	58
2005	485	8	3 758	55	4 243	48
2006	535	10	5 347	42	5 882	39
2007	663	24	7 684	44	8 347	42
2008	741	12	13 752	79	14 493	74
2009	883	19	19 875	45	20 758	43
2010	980	11	33 973	71	34 953	68

- China, Germany, Japan, Korea and Norway are the dominant producers in the ingot and wafer section of the PV industry value chain with additional manufacturing capacity in Switzerland, France and the USA. The global production capacity for wafers is estimated to be 30–35 GW, more than 55 % of which is in China. In Europe the large PV inverter companies are located in Germany, Spain, Austria, Switzerland, Denmark and Italy. Outside Europe, activities in this field are reported from Japan, the US, Korea and China. New market players and increased production have been reported from non-PVPS countries, particularly Taiwan, supporting the trend towards a further price reduction of the products.

- Total PV cell production for 2010 in the IEA PVPS countries is estimated to be 17,6 GW. Global PV cell production is estimated at 23 GW to 24 GW. The IEA PVPS countries account for around 75 % of this global production. China was the lead producer of PV cells in 2010 manufacturing around 9 GW of cells. This was more than double the 4 GW of cells estimated to be manufactured in China in 2009. Other PVPS countries manufacturing at the GW scale in 2010 include Germany with 2,7 GW, Japan with 2,3 GW and the US with 1,1 GW. These four countries together account for 87 % of the PV cell production in PVPS countries.

- The picture for PV module production is similar to that for cell production with 20,4 GW of wafer based and thin film modules produced in the IEA PVPS countries. Again the largest producers were China producing 10 GW, Germany 2,4 GW, Japan 2,7 GW and the USA with 1,3 GW. Other countries with over 500 MW of production were Spain, Korea and Malaysia. In total the PVPS countries produced over 18 GW of wafer based modules and 2,4 GW of thin film modules.

- Crystalline silicon accounted for 88 % of the modules produced in 2010. This is a higher proportion than in the previous three years when the proportion of crystalline silicon modules had been dropping. The shift is because the vast majority of new production in 2010, particularly in Asia, was crystalline silicon. Thin film accounted for 12 % of module production in IEA PVPS countries in 2010. Thin film module manufacturing is concentrated in a smaller number of countries; Switzerland, Germany, Japan, Malaysia, Mexico and the USA have a significant proportion of their manufacturing devoted to thin film modules.

- The PV industry ranges from small specialized companies to large multinational vertically integrated companies with manufacturing facilities spread across a number of countries. An increasing number of companies are strengthening vertical integration with in-house manufacture of wafers for their own cell and module production. The trend to moving mass production to low labour cost countries, particularly in Asia, also continued in 2010. Global cell production capacity increased dramatically during 2010 leading many commentators to warn of overcapacity in the market in 2011. Reductions in energy use during all stages of the manufacturing process continue with significant R&D efforts being devoted to further reductions. Globally the manufacturing capacity for high efficiency modules is increasing. Requirements for local content in PV systems installed also influenced manufacturing plans in some countries.

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

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Power installed during year in IEA PVPS reporting countries (MW)	24	24	30	38	62	74	116	207	288
Module production during year in IEA PVPS reporting countries (MW)	52		56		100	126	169	238	319

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Power installed during year in IEA PVPS reporting countries (MW)	371	481	1 058	1 367	1 639	2 465	6 146	6 265	14 192
Module production during year in IEA PVPS reporting countries (MW)	482	667	1 160	1 532	1 668	2 690	4 000 *(estimate)*	6 500 *(estimate)*	20 000 *(estimate)*

- On average, the cost of the PV modules in 2010 accounted for exactly 50 % of the lowest achievable prices that have been reported for grid-connected systems. In 2010 the average price of modules in the reporting countries was about 2,1 USD/W, a decrease of almost 20 % compared to the corresponding figure for 2009, following a decrease of 35 % the previous year.

- The lowest achievable installed price of grid-connected systems in 2010 varied between countries, with the average price of these systems being about 4,2 USD/W, about 13 % lower than the average 2009 price. Prices as low as just over 3 USD/W were reported; typically prices were in the range 3,2 USD/W to 4,9 USD/W.

- The total value of PV business in 2010 amongst the IEA PVPS countries approached 60 billion USD, double the figure for the previous year. Total direct employment approached 430 000 persons across research, manufacturing, development and installation, with steady annual increases in the reporting countries.

- Nearly all countries now offer or a planning feed-in tariffs for PV electricity. In fact the debate has now shifted from if or how to implement a feed-in tariff to how to move to the self-sustaining market post feed-in tariff. FiT approaches have successfully driven grid-connected PV investments in large-scale (multi-MW) plants, smaller-scale building-integrated applications and combinations of both. The FiT can be national-scale, state-based or even operate at the local community or utility level. They have been clearly seen as the prime mechanism for promoting strong growth in grid-connected PV applications.

- Worldwide, electricity utilities are now investing in very large-scale PV plants or asking how they can benefit from meeting their customers' interest in PV plants or PV electricity, often driven by government mandates and increasingly leading to the pursuit of business opportunities.

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

Australia	AUS	Muriel Watt & Robert Passey, IT Power Australia, Warwick Johnston, SunWiz, for the Australian PV Association
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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 Peter Ahm, Roland Bründlinger, Donna Munro and Greg Watt.

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Table 14 – currency exchange rates (average for calendar year 2009)

Country	Currency and code	Exchange rate (1 USD =)	Country	Currency and code	Exchange rate (1 USD =)
Australia	dollar (AUD)	1,09	Norway	krone (NOK)	6,05
Canada	dollar (CAD)	1,03	Sweden	krona (SEK)	7,20
Denmark	krone (DKK)	5,62	Switzerland	franc (CHF)	1,04
Israel	NIS	3,73	United Kingdom	pound (GBP)	0,65
Japan	yen (JPY)	87,76	United States	dollar (USD)	1
Korea	won (KRW)	1 155,43	China	(CNY)	6,77
Mexico	peso (MXP)	12,63	Austria, France, Germany, Italy, the Netherlands, Portugal, Spain	euro (EUR)	0,76
Turkey	Turkish lira (TRY)	1,50			

(source: OECD Main Economic Indicators 2011)

Exchange rates

Table 14 lists the reporting countries, corresponding currency codes, and the exchange rates used to convert national currencies. Exchange rates represent the 2010 annual average of daily rates (source: OECD Main Economic Indicators July 2011).

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 crystalline silicon technologies account for about 80 % of the overall cell production in the PVPS countries.
Single crystal silicon (sc-Si) PV cells are manufactured using a single crystal growth method and have commercial efficiencies between 15 % and 20 %. 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 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 specialized 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 61 215 Ed. 2, IEC 61 646 Ed. 2.0 and IEC 61 730 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› or ‹CEC› efficiency – of inverters is in the range of 95 % to 97 %, with peak efficiencies reaching 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) and play an increasing role in certain markets.

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, LiO) 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.

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