IEA INTERNATIONAL ENERGY AGENCY

TRENDS IN PHOTOVOLTAIC APPLICATIONS

Survey report of selected IEA countries between 1992 and 2009

PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

Report IEA-PVPS T1-19:2010

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 15th edition of the IEA PVPS international survey report on Trends in Photovoltaic Applications. 2009 has continued to evidence further market growth, signs of market consolidation and massive cost reduction. In total, about 6,2 GW of PV capacity were installed in the IEA PVPS countries during 2009 (2008: 5,5 GW); raising the total installed capacity to 20,4 GW in those countries. By far the greatest proportion (74 %) was installed in Germany and Italy alone. If the US, Japan and France are also included, then over 93 % of PV installations in 2009 occurred in five countries. The Israeli market took-off with an eighteen-fold increase while the Canadian market experienced a nine-fold boost – both driven by new and successful feed-in tariff schemes. A number of countries experienced an annual market increase of the order of two to four-fold – Australia, Austria, Switzerland, Germany, France, Italy, Japan and the Netherlands. The US annual market experienced 40 % growth. Overall, PV markets thus grow substantially in an increasing number of countries, although at different absolute levels. Grid-connected applications dominated in the reporting countries (about 99 % of the 2009 market) but the largely unsubsidized off-grid markets continued to grow worldwide, albeit less vigorously than the publicly funded grid-connected PV markets. On the supply side, total IEA PVPS country module production increased by over 60 % from 2008. Thin film production took off during 2009, particularly in Malaysia, Germany, the US and Japan. In 2009 the average price of modules in the reporting countries was about 2,6 USD/W, a decrease of 35 % compared to the corresponding figure for 2008. Prices as low as 3,5 USD/W were reported for grid-connected systems in 2009 but typically prices were in the range 4 USD/W to 6 USD/W. Finally, the total value of business in 2009 amongst the IEA PVPS reporting countries approached 30 billion USD. These are just a few highlights of this new edition of Trends in Photovoltaic Applications which I am confident will 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.

August 2010

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 15th international survey. It provides an overview of PV power systems applications, markets and production in the reporting countries and elsewhere at the end of 2009 and analyzes trends in the implementation of PV power systems between 1992 and 2009.

PV Production at Solan Hilber, Tyrol
(© photo: das fotoatelier Steinach)

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 $W \cdot m^{-2}$ 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.

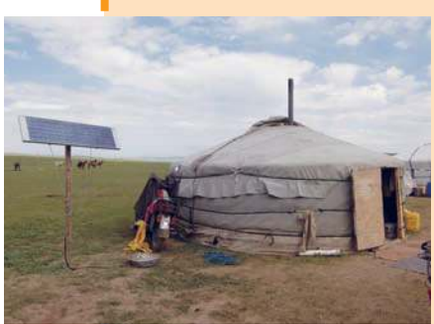
Currencies are either presented as the current national currency (where it is considered that the reader will receive most benefit from this information) or as euros (EUR) and / or US dollars (USD) (where direct comparisons between countries' information is of interest). Care should be taken when comparing 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.



Courtesy RTS Corporation, Japan

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.

Courtesy RTS Corporation Japan

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.

Figure 1 – PV System on a sport center in Challes les Eaux (Savoie Department) – 203 kW (Courtesy: Edisun Power)

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.

10 MW one-axis tracking c-Si Power Plant in Ferreira (photo Tecneira).

1.2 Total photovoltaic power installed

About 6,2 GW of PV capacity were installed in the IEA PVPS countries during 2009 (much the same amount as in the previous year) which brought the cumulative installed capacity to 20,4 GW. By far the greatest proportion (74 %) was installed in Germany and Italy alone. If the US, Japan and France are also included, then over 93 % of PV installations in 2009 occurred in five countries. Total PV capacity installed worldwide during 2009 is estimated to be a little over 7 GW.

Despite difficult economic conditions, there was growth (albeit relatively flat) of the annual PV market (ie the amount of PV installed during calendar year 2009) between 2008 and 2009. If Spain's explosive 2008 PV market and almost total collapse in 2009 are removed from the dataset, then the growth rate between the 2008 and 2009 annual markets for the remaining 20 countries becomes an impressive 84 % – a very healthy number during a period of global economic slowdown.

Table 1 – Reported PV power capacity in participating IEA PVPS countries as of the end of 2009

Country*	Cumulative off-grid PV capacity** (kW)		Cumulative grid-connected PV capacity (kW)		Cumulative installed PV power (kW)	Cumulative installed per capita (W/Capita)	PV power installed during 2009 (kW)	Grid-connected PV power installed during 2009 (kW)
	domestic	non-domestic	distributed	centralized				
AUS	40 770	43 140	97 210	2 530	183 650	8,3	79 130	68 570
AUT	3 605		48 991		52 596	6,4	20 209	19 961
CAN	15 190	20 010	12 250	47 120	94 570	2,8	61 850	54 140
CHE	4 000		67 040	2 560	73 600	9,7	25 700	25 500
DEU	45 000		9 800 000		9 845 000	119,6	3 845 000	3 840 000
DNK	165	375	4 025	0	4 565	0,8	1 300	1 200
ESP	31 000		3 492 000		3 523 000	76,1	60 000	60 000
FRA	23 000		407 000 installed/ 269 000 connected		430 000	6,7	250 200	250 000
GBR	620	1 125	27 845	0	29 590	0,4	7 077	6 922
ISR	2 644	260	21 611	14	24 529	3,4	21 500	21 000
ITA	5 000	8 000	656 800	511 500	1 181 300	20,3	723 000	723 000
JPN	2 635	91 998	2 521 792	10 740	2 627 165	20,7	482 976	479 152
KOR	983	4 960	93 300	342 672	441 917	9,1	84 400	84 400
MEX	18 037	5 687	1 296	0	25 020	0,2	3 270	796
MYS	10 000		1 063	0	11 063	0,4	2 287	287
NLD	5 000		58 169	4 338	67 507	4,1	10 669	10 578
NOR	8 080	450	132	0	8 662	1,9	320	0
PRT	3 050		99 150		102 200	9,5	34 250	34 150
SWE	4 448	721	3 535	60	8 764	1,0	854	516
TUR	1 000	3 500	500	0	5 000	0,1	1 000	100
USA	> 154 000	256 000	1 101 600	130 000	1 641 600	5,3	473 100	433 100
Estimated totals for all IEA PVPS countries (MW)	**837**		**19 543**		**20 381**		**6 188**	**6 113**

Notes:
**The UK has not yet provided a national survey report for 2009.*
*** 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.
Some countries are experiencing difficulties in estimating and/or apportioning off-grid domestic and non-domestic; in some markets the distinction between grid-connected distributed and centralized is no longer clear (eg MW scale plant in the urban environment), and mini-grids using PV are also emerging, with other problems of definition.
Where definition has not been made in a national report this is shown in this table, however the totals have been estimated using the most recently available ratio from the national reports applied to the current national data.
Australian off-grid domestic total includes 2 900 kW of PV on diesel grids.

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

Country	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
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	183,6
AUT	0,6	0,8	1,1	1,4	1,7	2,2	2,9	3,7	4,9	6,1	10,3	16,8	21,1	24,0	25,6	27,7	32,4	52,6
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
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
DEU	3	5	6	8	11	18	23	32	76	186	296	439	1 074	1 980	2 812	3 977	6 000	9 845
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
ESP	~	~	1,0	1,0	1,0	1,0	1,0	2,0	2,0	4,0	7,0	12,0	24,0	49,0	148,0	705,0	3 463,0	3 523,0
FRA	1,8	2,1	2,4	2,9	4,4	6,1	7,6	9,1	11,3	13,9	17,2	21,1	26,0	33,0	43,9	75,2	179,7	430,0
GBR	0,2	0,3	0,3	0,4	0,4	0,6	0,7	1,1	1,9	2,7	4,1	5,9	8,2	10,9	14,3	18,1	22,5	29,6
ISR	~	~	~	~	~	~	~	~	~	~	~	~	0,9	1,0	1,3	1,8	3,0	24,5
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	1 181,3
JPN	19,0	24,3	31,2	43,4	59,6	91,3	133,4	208,6	330,2	452,8	636,8	859,6	1 132,0	1 421,9	1 708,5	1 918,9	2 144,2	2 627,2
KOR	1,5	1,6	1,7	1,8	2,1	2,5	3,0	3,5	4,0	4,8	5,4	6,0	8,5	13,5	35,8	81,2	357,5	441,9
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
MYS	~	~	~	~	~	~	~	~	~	~	~	~	~	~	5,5	7,0	8,8	11,1
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
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
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
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
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
USA	43,5	50,3	57,8	66,8	76,5	88,2	100,1	117,3	138,8	167,8	212,2	275,2	376,0	479,0	624,0	830,5	1 168,5	1 641,6
Total	**103**	**127**	**151**	**181**	**219**	**281**	**355**	**471**	**678**	**966**	**1 337**	**1 818**	**2 876**	**4 243**	**5 683**	**8 019**	**14 193**	**20 381**

Notes: Totals reflect conservative 'best estimates' based on the latest information made available to the IEA PVPS Programme from the individual countries for previous years, and are updated as required. For example, the German data prior to 2008 (and the relevant totals) have been amended to incorporate the March 2010 information from the Working Group on Renewable Energy Statistics under the Federal Environment Ministry. Latest installed capacities are based on August 2010 information from Bundesverband Solarwirtschaft (BSW). The two sources of data have been integrated as seamlessly as possible, using estimates by IEA PVPS as required.

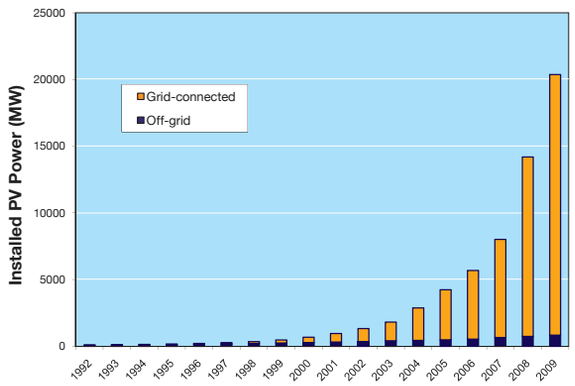


Figure 1 – Cumulative installed grid-connected and off-grid PV power in the reporting countries

This report continues to be updated to reflect the best information available at the time of writing which means that totals in some tables have been amended from previous years. This enables IEA PVPS to carry out a more realistic and rigorous evaluation of trends in PV markets and policies over the last decade or so. As expected, large and rapidly developing markets have presented challenges in accurately characterizing the annual installed PV capacity. However, the picture can become clearer as the PV market continues to mature – for example, since the beginning of 2009 in Germany the owners of new PV systems are legally obliged to register their systems with the German Federal Network Agency. Figure 1 illustrates the cumulative growth in PV capacity since 1992 within the two primary applications for PV. Particularly with the recent levels of growth seen in IEA PVPS member countries, this reported installed capacity represents a significant and increasing proportion of worldwide PV capacity.

The annual rate of growth of cumulative installed capacity in the IEA PVPS countries was 44 %, down from the record 77 % recorded in 2008. Five countries now rank in the GW cumulative installed PV capacity grouping. Germany's cumulative installed capacity grew at 64 % whereas Japan's growth rate exceeded 22 %, both higher growth rates than the previous year. Cumulative installed capacity in the US increased at over 40 % (the same as the previous year). Italy's cumulative installed capacity increased by a factor of more than two and a half.

Growth of the annual market was evident in a number of countries (Table 3). The Israeli market took-off with an eighteen-fold increase while the Canadian market experienced a nine-fold boost – both driven by new and successful feed-in tariff schemes. Particularly interesting is the number of countries that experienced an annual market increase of the order of two to four-fold – Australia, Austria, Switzerland, Germany, France, Italy, Japan and the Netherlands. The US annual market experienced 40 % growth. While annual growth decreased somewhat in both

Table 3 – Annual installed photovoltaic power (MW) in selected countries – historical perspective (1995–2009)

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
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
AUT	0,3	0,3	0,5	0,7	0,8	1,2	1,2	4,2	6,5	4,2	3,0	1,6	2,1	4,7	20,2
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
CHE	0,8	0,9	1,3	1,8	1,9	1,9	2,3	1,9	1,5	2,1	4,0	2,6	6,5	11,7	25,7
DEU	2	3	7	5	9	44	110	110	143	635	906	832	1 165	2 023	3 845
ESP	~	~	~	~	~	~	2,0	3,0	5,0	11,0	25,0	99,0	557,0	2 758	60,0
FRA	0,5	1,5	1,7	1,5	1,5	2,2	2,6	3,3	3,9	5,2	7,0	10,9	31,3	104,5	250,2
GBR	0,03	0,06	0,1	0,2	0,4	0,8	0,8	1,4	1,8	2,3	2,7	3,4	3,8	4,4	7,1
ISR	~	~	~	~	~	~	~	~	~	~	0,2	0,3	0,5	1,2	21,5
ITA	1,7	0,2	0,7	1,0	0,8	0,5	1,0	2,0	4,0	4,7	6,8	12,5	70,2	338,1	723,0
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
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	84,4
NLD	0,4	0,9	0,7	2,5	2,7	3,6	7,7	5,8	19,6	3,6	1,7	1,5	1,6	4,0	10,7
PRT	~	0,1	0,1	0,1	0,3	0,2	0,2	0,4	0,4	0,6	0,3	0,4	14,5	50,1	34,3
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	473,1

Notes: Countries that are experiencing (or have recorded in a past year) annual installed PV power of >5 MW.
See notes under Table 2 regarding the German data.

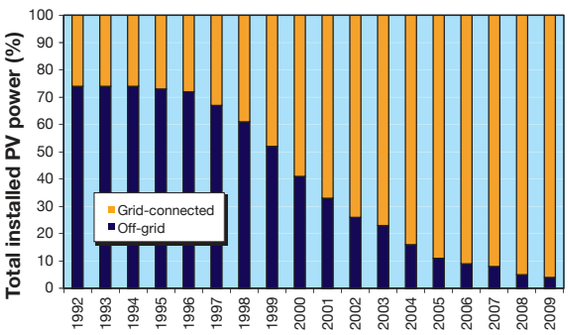


Figure 2 – Percentages of grid-connected and off-grid PV power in the reporting countries

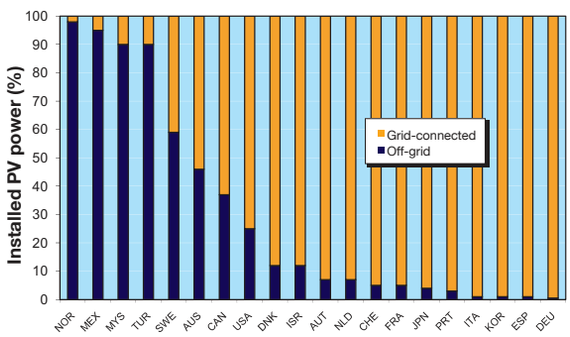


Figure 3 – Installed PV power in the reporting countries by application (%) in 2009

Korea and Portugal in 2009, in both cases 2008 represented large spikes in the PV capacity installed during the year. Compared to the 2007 annual markets, both Korea and Portugal enjoyed strong growth rates in 2009. In contrast the Spanish annual market almost totally collapsed in 2009 (to around 2 % of the 2008 market size and even less than the amount of PV installed back in 2006).

In 2009 the size of Germany's annual PV market was largest (the position previously held by Spain), exceeding any other country's annual market by more than 3 GW, with quite a drop to Italy followed by Japan and the US. Germany still has the highest level of installed capacity in terms of total capacity (approaching 10 GW) and by far the highest installed capacity per capita (almost 120 W/capita).

Of the total capacity installed in the IEA PVPS countries during 2009, only a little more than 1 % was installed in off-grid projects and these now make up about 4 % of the cumulative installed PV capacity of the IEA PVPS countries. It is interesting to note that it was only about one decade ago that the installed capacities of off-grid and grid-connected applications were divided almost equally. Figure 3 illustrates the proportion of various PV applications in the reporting countries. The largely unsubsidized market for vacation cottages, cost effective rural electrification, telecommunication and infrastructure applications does continue to grow worldwide, albeit less vigorously than the publicly funded grid-connected PV markets, with the cumulative installed off-grid capacity typically increasing steadily and predictably by about 10 % to 15 % each year.

Looking back over almost two decades of global cumulative installed PV capacity data it can be observed that the time taken for this capacity to double has been decreasing. Recently cumulative installed capacity has doubled less than every two years; around a decade ago the doubling period was about two years; in the early to mid 1990's the doubling period exceeded three years. At this rate, even with some unexpected setbacks, it would appear that the 2020 scenario outlined in the IEA's PV Roadmap – 200 GW installed capacity, producing 300 TWh of electricity per year and providing 1 % of global electricity generation – should be readily achievable.

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 79 MW of PV were installed in Australia in 2009, three and a half times the amount installed in 2008. Of this, nearly 87 % were grid-connected, taking the cumulative grid-connected portion to nearly 55 %, up from 30 % in 2008. Total installed capacity in Australia reached 183,6 MW. The Australian Government market incentive programmes Solar Homes and Communities Plan (SHCP) and the Renewable Remote Power Generation Programme (RRPGP) ended pre-purchase approvals in June 2009, but still accounted for 96 % of 2009 Australian Government PV expenditure. Support is now provided via market mechanisms.

The market for PV installations connected to central electricity grids continues to increase and represented the largest market for PV in 2009. The majority of installations took advantage of the government SHCP grant programme. The main

applications are rooftop systems for private residences, and community buildings. The commercial and light industry sector interest is also growing, with support available to selected projects in certain areas through the Solar Cities Programme. All grid-connected PV systems can create Renewable Energy Certificates (RECs) for the Renewable Energy Target. This mechanism and the Solar Credits REC multiplier took over from the grant based support mechanisms in June 2009. The second largest installed capacity of PV in Australia is for off-grid industrial and agricultural applications. These include power systems for telecommunications, signalling, cathodic protection, water pumping and lighting. Significant markets also exist for off-grid residential and commercial power supplies and increasingly for fuel saving and peak load reduction on community diesel grid systems. Some of this market was supported by government grants through the RRPGP.

The 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 of up to 5 000 AUD were available for system upgrades, if no previous rebates had been received. To be eligible, a household's income had to be less than 100 000 AUD per year. This programme had the most impact on the PV market in Australia during 2009, with 56,8 MW of PV installed. The vast majority of this (56,7 MW) was for grid-connected installations. A total of 84 MW of PV had been installed under this programme by the end of 2009.

The Australian Government has expanded the Renewable Energy Target (RET) to 45 000 GWh by 2020. The RET will continue to use the Renewable Energy Certificate (REC) mechanism, with each MWh of renewable energy generation eligible for one REC. REC multipliers, or Solar Credits, are available to PV systems, wind turbines and micro-hydro systems for the first 1,5 kW of capacity. As well as home-owners, organizations such as schools, community groups, businesses and developers are eligible for Solar Credits, and no means test will be applied. Typically trading at around 30 AUD to 40 AUD per REC, this can provide valuable capital cost reductions for small PV systems and will be one of the main market drivers in States with no gross feed-in tariffs. This programme, which follows on from grant based support schemes, has seen a rapid increase in the number of PV businesses, training and accreditation.

A range of State based feed-in tariffs now apply across most areas of Australia. Revisions have been announced for the ACT tariffs from 2010, with a reduction in residential tariffs and an increase in tariffs for larger systems. Consideration is being given to tariffs for systems above 30 kW. A gross feed-in tariff commenced in NSW from 2010.

In 2009, the Central Victoria, Moreland and Perth Solar Cities were launched and began offering energy saving products and programmes to their communities. All seven Solar Cities are now operational: Adelaide, Alice Springs, Blacktown, Central Victoria, Townsville, Perth and Moreland. Three Solar Cities installed a total of 735 kW of household PV systems in 2009. In addition, a total of 938 kW of PV systems was installed on commercial and iconic buildings.

The 480 million AUD National Solar Schools Programme (NSSP) commenced on 1 July 2008 and finishes on 30 June 2015. NSSP offers primary and secondary schools grants of up to 50 000 AUD to install solar and other renewable power systems, solar hot water systems, rainwater tanks and a range of energy efficiency measures including insulation, energy efficient lighting and ceiling fans. To May 2010, funding totalling more than 114 million AUD had been paid or approved to more than 2 500 schools. In addition, over 1 000 schools have reported their installations complete.

The Renewable Remote Power Generation Programme (RRPGP) provided rebates of up to 50 % of the capital cost of renewable energy and related components used for diesel displacement in stand-alone power systems. In 2009 a total of 3 180 kW of PV was installed in remote residences and 1 537 kW in non-residential systems. Of these systems, 477 kW of PV were installed and connected to the Norfolk Island diesel mini-grid.

Bushlight installs renewable energy systems in remote Indigenous communities (known as homelands) throughout central and northern Australia. Each system installation is preceded by, and carried out in conjunction with, a comprehensive programme of community engagement, education and training. In 2009, Bushlight installed five new renewable energy systems, with a combined total of 66 kW of PV. Bushlight also coordinates a maintenance programme that serviced more than 180 renewable energy systems, located in 150 communities, during 2009.

The Australian grid-connected PV market grew significantly in 2009, due to the rebates available through the Solar Homes and Communities Plan, and then through the Solar Credits Renewable Energy Certificate multiplier, operating as part of the Renewable Energy Target. State based feed-in tariffs, schools programmes and other support activities have ensured a strong market, which continues through 2010. The off-grid market, previously Australia's main PV market, no longer has any specific programme support, with the ending of the Renewable Remote Power Generation Program during 2009. Australia no longer has a local PV manufacturer; however Australian Government plans to encourage large-scale PV systems through a Solar Flagships Programme has increased international interest in the potential for companies to begin cell or module manufacture in the future.

Austria (AUT)

The Austrian PV market experienced a more than four-fold expansion in 2009 compared to 2008. During 2009, PV systems with a total power of 20,2 MW were installed compared to 4,7 MW the previous year, far exceeding the historical peak of 6,5 MW achieved in 2003. The cumulative installed PV capacity in Austria reached 52,6 MW at the end of 2009. Grid-connected applications increasingly dominate the market for PV, accounting for more than 93 % of the cumulative installed capacity by the end of 2009. As in previous years, the off-grid sector plays a minor role in the Austrian PV market, with only 0,25 MW installed during the year. An estimated cumulative capacity of 3,6 MW of off-grid systems for domestic and non-domestic applications has been installed in Austria by end 2009.

Before the implementation of the federal Green Electricity Act (Ökostromgesetz) in 2003, the Austrian framework for renewable energy support had been based on diverse local and regional incentives. Support in the form of preferential feed-in tariffs for electricity from renewable sources together with a purchase obligation for green electricity created a very attractive environment for investment in green electricity in general and PV in particular. However, with the capping of the availability of the PV feed-in tariffs at a national limit of 15 MW, the role of PV in the future electricity scenario was limited from the very beginning. After a period of about three years with no federal support for PV, Austria's parliament passed a revision of the GEA in May 2006, a minor revision in 2007, and a further revision in July 2008 that came into effect in September 2009. The latest revision regulates that an annual amount of 2,1 million EUR is available for funding new installations.

Feed-in tariff support for green electricity is limited to installations larger than 5 kW, and runs for 13 years. Installations smaller than 5 kW may receive investment funding, but are excluded from receiving feed-in tariffs. The PV feed-in tariffs for new installations are defined on a yearly basis in a separate Feed-in Decree. According to the 2009 Feed-in Decree the tariffs ranged from 0,4598 EUR/kWh to 0,3998 EUR/kWh for systems larger than 10 kW, remaining at approximately the same level as in previous years.

Besides the federal feed-in tariff scheme a new initiative was launched under the newly founded national Fund for Climate and Energy and provides rebates to newly installed private PV systems up to 5 kW in size. In 2009 a total budget of about 19 million EUR was allocated, with one million EUR dedicated to PV components in prefabricated houses.

As in previous years, in 2009 most Austrian provinces were running regional rebate programmes, aiming to overcome limitations of the federal incentives. Together with the federal schemes this created a healthy market for PV systems in 2009.

PV Production at Solan Hilber, Tyrol
(© photo: das fotoatelier Steinach)

Generally, the regional support was only granted where the installation was not supported by the federal feed-in tariff scheme. Through their rebate programmes the provinces supported an installed capacity of approximately 13,8 MW of PV in 2009, with Lower Austria leading with 1 750 new installations totaling 8,5 MW as a consequence of 20 million EUR of support. The incentive is based on a rebate of up to 3 000 EUR per kW installed, granted for residential installations up to 5 kW.

Unlike the situation in other European countries, the Austrian feed-in tariff system will only be responsible for a minor part of the supported PV in the country.

Canada (CAN)

Canada's total installed PV power capacity reached 94,6 MW in 2009 compared to 32,7 MW at the end of 2008. Grid-connected applications accounted for almost 88 % of the annual market in 2009 compared to only 33% the previous year. This is a significant transition for the Canadian PV industry that historically has mainly served the off-grid market. The growth in grid-connected systems was spurred by the Province of Ontario's Renewable Energy Standard Offer Programme initiated in 2006 and its Feed-in Tariff Programme launched in 2009.

2009 PV applications comprised 11 % residential and building integrated grid-connected systems, 76 % for three ground-mounted utility scale systems and 13 % for the unsubsidized off-grid applications. The domestic off-grid market remained at about 7 % of PV sales, primarily for remote homes and cottages, residential communication (radios), and recreational vehicles. The off-grid non-residential market for water pumping, road signals, navigational buoys, telecommunication repeaters, and industrial sensing, monitoring, and controlling represented 6 % of PV sales in 2009.

The Province of Ontario, under its Green Energy Act, launched its feed-in tariff (FIT) programme in September 2009 delegating responsibility for its

implementation to the Ontario Power Authority (OPA). The FIT programme replaced the province's highly popular Renewable Energy Standard Offer Programme (RESOP), which underwent review in 2008. As of the third quarter of 2009, the OPA was responsible for 1 422 MW of renewable energy supply capacity of which 525,4 MW were PV power generation projects under the RESOP Programme. Of these, Canada's first three large-scale PV parks (9,1 MW, 10 MW and 20 MW) achieved commercial operation in 2009 and became eligible for RESOP contract payments of 0,42 CAD/kWh under 20 year power purchase agreements.

In the fourth quarter of 2009, RESOP was replaced by the feed-in tariff programme, North America's first comprehensive guaranteed pricing structure for electricity production from renewable fuel sources including solar PV, bioenergy, waterpower and wind. The feed-in tariff programme is divided into two streams; one targets the renewable energy projects generating more that 10 kW of electricity (referred to as the FIT Programme); and the other targets small renewable energy projects of 10 kW or less, such as a home or small business installations (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 applicants are paid a fixed price of up to 0,802 CAD/kWh for the electricity they generate for a 20 year contract period.

A number of other initiatives are underway, such as the Canada Mortgage and Housing Corporation's (CMHC's) EQuilibrium™ Sustainable Housing Demonstration Initiative that brings together the private and public sectors with the goal of developing homes that are designed and constructed based on the principles of occupant health and comfort, energy efficiency, renewable energy production, resource conservation, reduced environmental impact, and affordability. As of 2009, six projects have been completed or were at various stages of development. The PV production from four projects will be monitored for a one year period and live feed of the results will be provided.

It is considered that the Feed-In Tariff Programme (and RESOP) is a major step towards developing a competitive, strong Canadian solar industry. The FIT programme has addressed many of the concerns regarding the delays and interconnection obstacles identified by CanSIA and other renewable energy industry associations during the review process of the RESOP and the process is now less complicated for applicants. The significant initial response to the microFIT programme signals a strong support for development of residential PV rooftop applications in Ontario.

Denmark (DNK)

By the end of 2009 Denmark (including Greenland) had about 4,6 MW of PV installed in total, an increase of 1,3 MW compared to 2008. Grid-connected distributed systems accounted for over 92 % of the annual market in 2009 and make up the majority (88 %) of PV systems in Denmark. The national electricity grid covers practically the whole country and leaves little room for stand-alone applications. In Greenland stand-alone PV plays a major role as the power source for remote signalling and for the telecommunication network extending more than 2 000 km along the western coastline.

The electricity utility DONG reported about 0,5 MW of PV installed during 2009 and the utility EnergiMidt an additional 0,5 MW, the rest being installed by various market actors. Denmark has no general incentive for reducing the investment cost of PV systems but has a net-metering scheme for private households and institutions set by law. In 2009 the Public Service Obligation (PSO) of the Danish transmission system operator Energinet.dk, the so-called ForskEL and ForskVE programmes, funded about 10,4 million DKK for applied research and demonstration projects in PV. A major demonstration project, Photo-Skive, targeting 1 MW of BIPV on the buildings of the Skive municipality has received 22 million DKK in support from the ForskVE programme and during 2009 implemented about 300 kW of PV. The ForskVE programme is expected to support the implementation of up to 5 MW of PV on the island of Bornholm as an integral part of the ECO-GRID project; this will correspond to a PV penetration of 10 % in the electricity grid of Bornholm.

In early 2004 the Danish Energy Authority (EA) in collaboration with the electricity sector, the industry and other key stakeholders finalized a national strategy on PV after a public hearing. Initially revised in 2006, a more comprehensive revision of the PV strategy including deployment issues was initiated in 2008 and completed by end 2009.

In 2009 the government confirmed its commitment to support renewable energy in its annual Statement of Energy, in conjunction with the new energy plan, A Visionary Energy Policy, extending to 2025. Public funding for R&D into energy is on track to double from about 0,5 billion DKK in 2007 to one billion DKK by 2010. Efforts are still ongoing to establish relatively large scale PV deployment/ demonstration programmes, while investment incentives are still required. However, despite consumer polls indicating that many homeowners can accept pay-back periods of up to 20 years for a PV roof-top system and the relatively small need for public support that this implies, there are no suggestions in the government's energy plans, that support may be forthcoming. PV is not even mentioned in the otherwise ambitious plans for renewable energy deployment.

France (FRA)

During 2009 about 250 MW of PV were installed in France (mainland France, Corsica and the four French overseas departments Guadeloupe, Guyane, Martinique and Réunion), a more than twofold increase compared to 2008, which in turn had seen a more than threefold increase compared 2007. The growth is mainly due to the success of national fiscal measures (feed-in tariff and tax credit) in operation since 2006. The French Government decided to place an emphasis on BIPV and reflected this in the feed-in tariff structure. Grid-connected distributed systems and grid-connected centralized systems accounted for almost the entire annual market. Cumulative installed capacity at the end of 2009 was 430 MW of which about 95 % are grid-connected.

Nearly 40 % of the total capacity installed in mainland France in 2009 involved large-scale roof-mounted modules; large surface-area farm building applications were particularly popular. Growth in the numbers of ground-based PV power plants continued throughout 2009 with a number of projects totaling some 60 MW of installed capacity. There can be a significant time lag between projects being launched and their actual implementation, attributable to both technical development requirements and the administrative procedures taking more time than for other segments of the PV market. Consequently, at a given point in time in such a market, there can be discrepancies between the total capacity installed and the power connected to the national grid, due to delays in handling connection requests.

In 2009 in mainland France the feed-in tariff for photovoltaic generated electricity was 0,32823 EUR per kWh with a building integrated PV (BIPV) bonus of 0,27353 EUR per kWh. Higher feed-in tariffs are available in Corsica and the French overseas departments. Feed-in tariff contracts are signed for a 20 year period and are revised every year on the basis of a specific inflation index. Proceeds from the sale of PV electricity are (as of 2009) exempt from income tax when the nominal power of the photovoltaic system does not exceed 3 kW.
It was found that, because of the tariff advantages offered to BIPV installations, many investors have developed otherwise empty structures (farm out-buildings, shade structures and so on) in order to qualify for the higher tariff. Further, in September 2009, the government confirmed its intention to bring in an intermediary tariff of 0,45 EUR per kWh for 'simplified' installations integrated into professional buildings, such as commercial premises and industrial warehouses. New pricing rules are implemented from January 2010, together with rules for classifying the various projects which will be able to take advantage of these rates and will reduce elements of speculation that would ultimately lead to higher electricity prices.

Figure 2 – Photovoltaic power plant in Vinon sur Verdon (Var department) – 4,2 MW. (Courtesy: Solaire Direct)

Other measures complemented the feed-in tariff support programme, namely an income tax credit applying to 50 % of PV module and other equipment costs and capped at 8 000 EUR per income tax paying person (16 000 EUR for a couple), and the ongoing ADEME – FACE support for off-grid systems. Regional support is also available for PV deployment. France's 'Grenelle of the Environment' plays an important role in influencing the ways in which the PV market is to evolve over coming years. Associated with this initiative, a target has been announced of 1 100 MW of installed PV capacity by 2012, reaching 5 400 MW by 2020, there has been confirmation that tariff incentives will remain in place until 2012 plus the creation of an additional tariff for PV in large-sized buildings, and an invitation to tender has been issued for the construction of a least one PV power plant per region in France by 2011, to provide a further 300 MW of installed PV capacity.

Germany (DEU)

By the end of 2009 the cumulative installed PV capacity in Germany was about 9,8 GW, with around 3,8 GW of PV being installed during the year. In 2009 around 159 850 new PV systems with a total capacity of over 3,8 GW were registered with the German Federal Network Agency. In addition to the market for grid-connected systems, there is a steady demand for stand-alone systems. Rough estimates suggest that in 2009 around 4,5 MW of stand-alone PV systems were installed, mainly for industrial applications. Renewable energies are one of the most prominent topics on the political agenda in Germany. The new Federal Government elected in September 2009 confirmed this priority in its coalition agreement. In 2009 renewable energies achieved a share of 16,1 % of domestic electricity production, surpassing the initial target of 12,5 % by 2010. The target of 20 % by 2020 has now been extended to 30 %. The main driving force for the PV market in Germany is the Renewable Energy Sources Act (EEG). The EEG determines the procedures for grid access for

renewable energies and guarantees them favourable feed-in tariffs. Particularly in the second half of 2009 the installation of PV systems in Germany was boosted by a combination of the EEG and a decrease of PV system prices of roughly 30 % compared to 2008.

In late 2008 it was decided to raise the yearly degression rate of the EEG PV feed-in tariff in order to stimulate a stronger PV price reduction. For example, for roof-top PV systems smaller than 100 kW installed capacity, the yearly degression rate changed from 5 % to 8 %. The resulting tariffs for 2009 were 0,3194 EUR/kWh for ground mounted systems and 0,4301 EUR/kWh, 0,4091 EUR/kWh, 0,3958 EUR/kWh and 0,33 EUR/kWh respectively for roof-top PV systems smaller than 30 kW, 100 kW and 1 MW, and larger than 1 MW. In addition, a mechanism was introduced to adapt the degression rate to the magnitude of PV market growth. If the market deviates from a pre-defined corridor, the degression rate is increased or decreased accordingly by 1 % the following year. For 2009 the corridor was set at between 1 000 MW and 1 500 MW. Further, from 2009 the PV system owner can receive a reimbursement for own consumption of the PV electricity, where the system size is below 30 kW installed capacity. Interestingly, following significant decreases in PV system prices, the scheme has been further fine-tuned. After an initial decrease of the EEG tariffs at the beginning of 2010 an additional two-step reduction during 2010 has been decided upon.

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

Israel (ISR)

During 2009 Israel was the top performing country with respect to relative growth of the annual PV market, with a more than twenty-fold increase over the previous year and 21,5 MW installed. There has been a complete turnaround in the nature of the Israeli PV market with grid-connected systems now accounting for 88 % of the cumulative installed capacity of 24,5 MW by the end of 2009.
The grid-connected market exploded as a result of the introduction of a PV feed-in tariff during 2008 and its operation for a full year in 2009. The FiT started at 2,04 NIS/kWh in 2008 and was amended to 1,97 NIS/kWh in 2009. It is anticipated that it will be reduced to 1,55 NIS/kWh for the period 2011 – 2014. This first stage of the programme was for household and small commercial applications of PV systems, up to 15 kW and 50 kW in size respectively. The original quota of this stage was set at a total of 50 MW. Further stages of the programme are envisaged for 2010, with quotas of 300 MW for PV plants up to 10 MW in size and 500 MW for PV and solar thermal plants larger than 10 MW.

Also in 2009, Israel's first Concentrator Photovoltaic (CPV) field (developed by an Israeli company) was installed, consisting of several solar dishes each with a capacity of 4,5 kW electric and 10,5 kW thermal.

Italy (ITA)

In 2009 723 MW of PV power were installed in Italy, more than twice the size of the market in 2008 and second in magnitude behind only the German market. Cumulative installed PV power reached almost
1,2 GW. The grid-connected centralized PV power systems market is growing particularly rapidly and now accounts for 43 % (up from 33 %) of the total installed capacity; grid-connected distributed PV systems now account for 56 % of the total installed capacity.

Off-grid PV applications continue to decrease in relative importance. Interestingly, while off-grid non-domestic applications are slowly increasing in number, the total installed power for off-grid domestic systems is decreasing because of decommissioning of systems installed in the early 1980's.

The national market stimulation initiative in operation during 2009 is the Conto Energia Programme. The first stage, Primo Conto Energia, was completed toward the end of 2009 with 5 733 PV plant installations (corresponding to about 165 MW). The second stage, Nuovo Conto Energia, was defined by governmental decree in February 2007 and together both stages have resulted in 71 284 PV plants, corresponding to about 1 142 MW of capacity. The limit of 1 200 MW PV supported by Conto Energia is expected to be reached by July 2010.

The rapid market growth seen in 2008 and 2009 was driven by the changes to the feed-in tariff decree which were adopted in early 2007. The feed-in tariff value depends on the degree of PV integration in the building, up to 0,4802 EUR/kWh in 2009, but reduced for large plants (for example, a large free-standing plant could earn 0,3528 EUR/kWh in 2009).

PV in Israel, Courtesy SolarEdge Technologies

Each year the relevant price values paid are reduced by 2 % per calendar year, and the tariffs remain valid for 20 years. Additional amounts are earned for the sale of electricity to the grid or for own consumption of the electricity. Some regional grant support for BIPV is also available.

A new governmental decree, expected before end 2010, will redefine the maximum PV capacity to be supported and the appropriate feed-in tariffs for PV plants commissioned after 2010. Also under development is a national law to promote the use of PV (of at least one kW capacity) in new buildings.

Japan (JPN)

During 2009 a total of about 483 MW of PV was installed in Japan, more than twice the amount installed the previous year. The primary factors leading to the accelerated growth were the restart of a subsidy programme for residential PV systems and the start of a new programme to purchase surplus PV power, based upon the Act on the Promotion of the Use of Non-Fossil Energy Sources and Effective Use of Fossil Energy Source Materials by Energy Suppliers. Of the PV systems installed in 2009 almost 99 % were grid-connected distributed applications, mainly residential PV systems. In 2009 cumulative installed PV capacity in Japan exceeded 2,6 GW.

The financial year (FY) 2009 national budgets for PV power generation from the Ministry of Economy, Trade and Industry (METI) totaled 49 560 million JPY (about twice the amount allocated in FY 2008). Of particular significance 43 050 million JPY were allocated for market revitalization, up from 10 700 million JPY the previous year. Major projects and budgets in FY 2009 for new and renewable energy (mainly PV) by METI and the Ministry of the Environment (MoE) included: Subsidy for Installation of Residential Photovoltaic Systems, Technology Development of Photovoltaic Power Generation, Field Test Project on New Photovoltaic Power Generation Technology, 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, Project for Supporting New Energy Operators, Project for Promoting the Local Introduction of New Energy, Project to Introduce and Promote New Energy Measures, Project for Establishing New Energy and Energy Conservation Visions at the Local Level, Project for developing technology to prevent global warming, Project to promote comprehensive measures to create low-carbon local communities and Project to promote the use of PV and other types of renewable energy. In addition, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and other ministries and agencies are also promoting the introduction of PV power generation.

Igara Nursery School 5.09 kW
Foto Courtesy RTS Corporation, Japan

The number of applications submitted between January and December 2009 for subsidy of residential PV systems exceeded 117 000. This programme is scheduled to continue throughout 2010. By the end of FY 2009 the cumulative number of installed residential PV systems that have received a subsidy in Japan and their associated installed capacity reached approximately 600 000 projects and 2 200 MW respectively. In response to the resumption of the subsidy programme for residential PV systems by METI, over 500 municipalities also started implementing their own support programmes for residential PV.

In July 2009, METI enacted the Act on the Promotion of the Use of Non-Fossil Energy Sources and Effective Use of Fossil Energy Source Materials by Energy Suppliers, which obliges electricity utilities to purchase surplus PV power. From November 2009 electricity generated by residential PV systems with capacity less than 10 kW is eligible to be purchased at 48 JPY/kWh (almost double the domestic electricity price). In the case of a combination of a PV system with a capacity below 10 kW and an additional power generation facility (e.g. a fuel cell), the purchase price is 39 JPY/kWh. For non-residential PV systems and PV systems with a capacity of between 10 kW and 500 kW, the purchase price is 24 JPY/kWh. The prices are expected to be reviewed annually and all users of electricity will contribute towards the associated costs. The electricity utilities themselves have plans to construct PV power plants with a total capacity of 140 MW at 30 locations across Japan by 2020. So far utilities have announced specific plans for the construction of 18 PV power plants nationwide with a total power generation capacity of about 100 MW.

Looking forward, the New Energy and Industrial Technology Development Organization (NEDO) reviewed its 2004 PV technology roadmap, bringing forward the original time-frames by three to five years, and renamed it PV 2030+ (with an outlook now to 2050). The government also increased the

Malaysia Energy Commisison Building, 71.5 kWp, Putrajaya

target for PV installed capacity in Japan by FY 2020 from 14 GW to 28 GW.

Korea (KOR)

The cumulative installed power of PV systems in Korea increased to almost 442 MW by the end of 2009. The annual installed PV power during 2009 fell to 84,4 MW, less than one third the size of the market in 2008, mainly due to a reduction in the feed-in tariff rate impacting more severely on development of larger sized (multi-megawatt) plants. Grid-connected centralized systems accounted for almost 78 % of the total cumulative installed PV power by the end of 2009. Grid-connected distributed systems amounted to 21 % of the total cumulative installed PV power (up from 15 % the previous year) and these were mainly installed under the feed-in-tariff scheme and the 100 000 roof-top programme. The share of off-grid non-domestic and domestic PV systems has continued to decrease to a little over one percent of total cumulative installed PV power.

In 2009 the total public budget for PV was 401 469 million KRW, a 47 % increase over the 2008 budget. Significantly, the budget for market incentives was 330 830 million KRW, an increase of 54 % compared to 2008. The Ministry of Knowledge Economy's Third Basic Plan on New and Renewable Energy Sources R,D&D (released in 2008) proposes the construction of one million green homes and 200 green villages by 2020. In support of this, the government provides 60 % of the initial PV system cost for single-family and private multi-family houses, and 100 % of the cost for public multi-family rental houses. During 2009, the programme supported 14 895 households, with an installed PV capacity of 13,5 MW. By the end of 2009, a total of 38 535 households had benefited from this programme resulting in 43,7 MW of installed PV capacity.
From late 2008 the feed-in tariff rate was reduced - relatively more significantly for larger sized PV plants. However the cap was increased from 100 MW to 500 MW, and beneficiaries can also choose between periods of 15 years and 20 years. In 2009, 50 MW were installed under the programme, with an annual spending of 236 700 million KRW (twice the 2008 amount). It is planned that a Renewable Portfolio Standard will replace the existing feed-in tariff scheme from the year 2012, and grid parity is anticipated around 2020 in Korea. Prior to the start of the RPS, the Government has initiated a RPS demonstration programme to run from 2009 until 2011, involving an installed PV capacity of 101,3 MW. Six electricity utilities will construct their own PV plants or purchase PV electricity from privately-owned plants. In 2009, 12,5 MW of PV were installed under this programme.

Under the Deployment Aid Programme the Government provides 60 % of the installation cost for conventional PV systems with a capacity below 50 kW and 80 % for special purpose demonstration systems. During 2009, 132 PV systems totaling of 6,0 MW of capacity were installed. Grid-connected PV systems ranging in size from 5 kW to around 200 kW were installed in schools, public facilities, welfare facilities and universities.

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

Malaysia (MYS)

By the end of 2009 Malaysia had a total installed PV capacity of over 11 MW, of which about 90 % were off-grid PV systems. During 2009 there were 287 kW of grid-connected PV systems installed and an estimate of almost 2 MW off-grid systems. The largest grid-connected PV system commissioned in 2009 in Malaysia has a capacity of 71,5 kW and is located at the new Energy Commission head office in Putrajaya.

Although off-grid PV applications currently dominate the Malaysian PV market, it is envisaged that by the end of the 10th Malaysia Plan in 2015 there could be at least 65 MW of grid-connected PV systems. This quantum leap is expected to result from the introduction of the proposed national feed-in tariff in mid 2011 (the start of the 10th Malaysia Plan).

Currently the grid-connected PV market is driven largely by financial incentive programmes implemented under the national MBIPV Project (such as the SURIA 1000 Programme, Demonstration and Showcase Incentive Programmes). Collectively, these funding programmes will result in an estimated 2 MW of grid-connected PV systems being installed by the end of 2010. SURIA 1000 was based on a bidding process, spread over six calls that were completed toward the end of 2009. The Showcase Incentive provided a 100 % capital incentive with a capacity target of 125 kW; SURIA for Developer provided a 35 % capital incentive with a 340 kW capacity target; and the Demonstration Incentive provided a 25 % capital incentive with a 205 kW capacity target.

Significant policy commitments were forthcoming during 2009. In July, the Prime Minister announced the National Green Technology Policy, including the feed-in tariff mechanism that would be implemented in the 10th Malaysia Plan, and in October the Prime Minister, in his National Budget 2010 speech, announced the establishment of a Green Technology Fund of 1,5 billion Malaysia Ringgit (454 million USD) to provide soft loans to companies that supply and/or utilize green technology.

Mexico (MEX)

During 2009 almost 3,3 MW of PV were installed in Mexico, bringing the cumulative installed capacity to over 25 MW. The share of grid-connected PV capacity amounted to about one quarter of the annual market in 2009. By the end of 2009, off-grid domestic applications continued to dominate the Mexican PV market accounting for 72 % of the cumulative installed PV power.

The private sector played an important role in grid-connected PV projects during 2009. A 400 kW system was installed at the facilities of an American automobile manufacturer in the northern state of Coahuila. Also, one of the main supermarket chains continued with its programme to incorporate renewable energy for the supply of green energy to its stores, installing a 200 kW roof-mounted PV system in the city of La Paz.

The momentum for growth of the Mexican PV market also continued building at the governmental level through the issuing of rules concerning the Law of Use of Renewable Energy and Financing of the Energy Transition (released during the third quarter of 2009). In this respect, a draft contract model that would allow interconnection of PV systems with capacities up to 500 kW was issued by the Energy Regulatory Commission. By the end of 2009 some states within Mexico had initiated discussions that may lead to the installation of megawatt-scale PV power plants during 2010.

The Netherlands (NLD)

During 2009 about 10,7 MW of PV (around 99 % grid-connected) were installed in the Netherlands, bringing the cumulative installed capacity to 67,5 MW. This represented about a two and a half times expansion of the annual market of the previous year.

A feed-in tariff scheme, Stimulation Sustainable Energy Production (SDE) commenced in 2008 for small scale PV installations. The initial tariff was for an additional 0,33 EUR/kWh for PV electricity delivered to the national electricity grid for a period of 15 years. In 2009, due to overwhelming public interest in the SDE, an additional budget of 50,8 million EUR (on top of the initial 88 million EUR) was allocated to allow a further 11,8 MW to be installed in coming years. Also in 2009, the additional tariff for small systems (0,6 kW to 15 kW capacity) was reduced to 0,253 EUR/kWh and larger systems (up to 100 kW capacity) were supported with an additional tariff of 0,383 EUR/kWh. The additional tariffs are added to utility payments of 0,273 EUR/kWh and 0,076 EUR/kWh for small and large systems respectively.

Several cities in the Netherlands have their own PV projects in newly built areas or associated with renovation projects. One of the largest is a joint initiative of three cities – Heerhugowaard, Alkmaar and Langedijk (HAL) – which commenced in 2009 and aims to install 5 MW of PV on roof tops. The project is supported by the European Framework Programme Sun Cities.

Norway (NOR)

About 320 kW of PV were installed in Norway during 2009, entirely in off-grid systems, with the annual market around the same level as that of the previous four years. Off-grid domestic applications account for over 93 % of Norway's cumulative installed PV capacity of close to 8,7 MW.

There were no PV demonstration, field test or market stimulation programmes in Norway during 2009. However, Norwegians have used PV technology for more than three decades, especially in recreational houses. Accounting for 80 % to 90 % of the Norwegian PV market, an increasing number of users now purchase additional PV capacity to serve home appliances such as television, freezers, refrigerators, IT equipment and so on. Replacement of older systems also creates some market growth. An increasing amount is being spent on high quality, maintenance-free batteries that cost two to three times as much as ordinary batteries.

Professional users also constitute an important part of the market. Even north of 70° latitude lighthouses are powered by PV, provided with a NiCd battery bank that ensures power supply during the dark winter months. A typical storage capacity is 120 days without power from the PV system. Approximately 2 890 installations serving lighthouses and coastal lanterns have been installed.

Whereas the PV market remains small, the highlight of the Norwegian PV story remains the remarkable industrial development of a number of businesses along the PV value chain and the associated R&D support from government. In particular, the Renewable Energy Corporation (REC) with PV cell and module plants in Norway, Sweden and Singapore and a majority shareholding of REC Silicon in the US, ranks as one of the most impressive of the global PV manufacturers.

Portugal (PRT)

Over 34 MW of mostly grid-connected PV were installed in Portugal during 2009. Although this represented a decrease compared to the 50 MW installed in 2008, that year represented a particularly dramatic expansion of the market. Portugal's cumulative installed PV capacity reached 102,2 MW by the end of 2009. Grid-connected systems (mostly centralized) account for 97 % of the cumulative installed capacity in Portugal.

The most significant policy initiative driving this market growth is the continuation of the independent power producer (IPP) law within the PV legal framework. The IPP law sets feed-in tariffs according to renewable technology and was revised in 2007. The current PV legal framework has the following classes: independent power producer, with no upper installed capacity limit, and feed-in tariffs from 0,317 EUR/kWh to 0,469 EUR/kWh; producer-consumer, with installed capacity limit of 150 kW, and feed-in tariff about 0,291 EUR/kWh; and micro-generation, with installed capacity limit of 5,75 kW, and a premium feed-in tariff of 0,65 EUR/kWh.

In 2009 about 23 MW of PV were installed under the independent power producer framework (including four large projects of 1,44 MW, 5 MW, 6 MW and 10,1 MW). Under the micro-generation scheme about 11 MW of PV were installed during 2009.

Other measures stimulating the PV market included a reduced VAT rate on renewable equipment, custom duties exemption and income tax reductions on solar equipment (up to about 800 EUR).

Spain (ESP)

Essentially the Spanish PV market collapsed in 2009, with about 60 MW installed during the year, compared to 2,7 GW in 2008 and about 0,5 GW in 2007. However 2009 also saw pre-registration of future capacity to be installed amounting to 161 MW of roof-top PV and 341 MW of ground-based PV systems. Currently the distribution of PV installations in Spain is about 99 % grid-connected systems and 1 % off-grid systems, with more than 50 000 PV systems installed.

Following mounting concern about the growth rates experienced in the Spanish PV market in 2007 and 2008, the speculative nature of some investments, the relative lack of PV installations in the residential sector and the degree of PV product competition provided by cheap imports (particularly from China) dramatic changes to the support scheme were introduced late in 2008 (Royal Decree 1578/2008 published September 2008). In particular, the feed-in tariff is subject to a new classification of eligible PV plants – Type I installations (PV roof-top plants or plants developed for similar surfaces), made up of Type I.1 (PV plants with a capacity equal to or less than 20 kW) and Type I.2 (PV plants with a capacity greater than 20 kW); and Type II installations (any other type of plant - essentially ground-based PV plants). Individual installed capacity limits were set at 2 MW for Type I plants (increased in June 2009 to 10 MW) and 10 MW for Type II plants.

In addition, a number of administrative checks and balances were introduced. Quotas were introduced for the amount of PV power able to be installed each year (267 MW for roof-top systems and 233 MW for ground-based systems in 2009), and the feed-in tariffs were reduced considerably and subjected to degression provisions, By the end of 2009 the applicable feed-in tariffs were 0,34 EUR/kWh,

PV on Roof, Spain, 2009, Copyright P. Huesser

0,32 EUR/kWh and 0,28 EUR/kWh for Type I.1, Type I.2 and Type II installations, respectively (note: the large investor-owned PV farms of the past, made up of many 100 kW systems, were benefitting from the feed-in tariff of 0,44 EUR/kWh allocated for systems between 5 kW and 100 kW installed capacity).

In addition in 2009 a Royal Decree Law was published regarding elimination of the tariff deficit carried by the electricity companies, such that from the beginning of 2013 access tariffs should be able to cover the costs of all regulated activities – in transition, the Royal Decree Law provides for the allocation of some costs currently integrated in the electricity tariff to the Spanish State Budget.

Sweden (SWE)

Annual installed PV power in Sweden in 2009 fell to 854 kW – half the amount of the previous year – as a result of no subsidy scheme being in operation for the first half of the year and delays in the distribution of the new subsidy in the second half of the year. Grid-connected installations accounted for 60 % of the market during 2009. The cumulative installed power of PV systems in Sweden increased to almost 8,8 MW by the end of 2009. The share of grid-connected systems increased to 41 % of the total cumulative installed power. The off-grid PV markets are quite stable with roughly 300 kW being installed each year.

A new direct subsidy for grid-connected systems, similar to the one that existed between 2005 and 2008, started in July 2009 and will run until the end of 2011. The new subsidy provides for 60 % of project costs (previously 70 %), 55 % for larger companies, to a maximum of two million SEK to cover system components, installation and planning. Additionally, the subsidy is now open to every type of system and owner (compared to only being previously available for BIPV on public buildings), on any type of estate so long as it has a building permit. Initially the funds were split between the years as follows: 50 million SEK in 2009, 60 million SEK in 2010 and 50 million SEK in 2011. However, with a large interest shown in the first call (applications totaling 200 million SEK), the government decided to add an additional 50 million SEK to the 2009 budget.

A number of interesting regional initiatives exist in Sweden to promote deployment of PV. Solar Region Skåne was formed 2007 by the local energy agency, the University of Lund and Malmö City and acts as a centre for PV knowledge and as a place to meet other actors in the PV community. Amongst its activities are PV seminars, counseling, courses, events, exhibitions and study visits. The organization has also been involved in installing a significant portion of Sweden's grid-connected PV and continued to do so in 2009 with a 100 kW system. In 2009 a solar cell community in the Sala and Heby municipality made an agreement with the local power utility, Sala Heby Energi AB, which guaranteed purchase of PV electricity (from two PV systems initially) at a higher price than the normal electricity market price – thus forming Sweden's first feed-in tariff scheme. Currently members of the community own shares of the PV systems and are entitled to a share of the profits. The initial profits will be spent on expanding the two PV systems and adding further systems to the scheme.

100 kW Sege Park system, Sweden
Courtesy Jonas Bengtsson

The outlook for installed capacity in calendar year 2010 is positive with systems that were started in 2009 being completed plus the installation of systems selected in the 2010 call. However, while there is a general appreciation of the new broad-based subsidy there is a feeling that the 210 million SEK budget is too low given the current level of public interest in PV. There are also concerns expressed about what will happen with respect to PV policy after 2011.

Switzerland (CHE)

Annual installed PV power in Switzerland in 2009 reached 25,7 MW – more than twice the size of the annual market the previous year. Over 99 % of the systems installed were grid-connected and grid-connected capacity now makes almost 95 % of Switzerland's cumulative installed PV capacity of 73,6 MW.

In 2007 the Swiss parliament adopted a revised Energy Act, including a preferential feed-in tariff scheme for renewable energies. This commenced operation at the beginning of 2009 and drove the strong demand for grid-connected PV systems throughout the year. The feed-in tariff scheme is similar to the German model, with different prices for small and large systems, and also variations according to whether the systems are roof mounted, ground mounted or can be classed as BIPV. The term of payments is 25 years and the scheme is in effect capped to about 30 MW in total, with a review scheduled for 2010.

Also in 2009, as a consequence of the global financial crisis, stimulation funding was made available in the form of direct subsidies – at the Federal level about 20 million CHF in total provided as grants of 2 900 CHF/kW of PV installed, and a similar amount

in aggregate from a number of Cantons. PV installations funded by these direct subsidies do not qualify for the enhanced feed-in tariff for at least three years.
In addition to these measures, the well-known Swiss solar stock exchange schemes provided by several large electricity utilities are continuing to function well and it is expected that these will continue to provide an additional steadily growing market for PV.

Turkey (TUR)
One MW of PV was installed in Turkey during 2009, with off-grid applications accounting for 90 % of the annual market. While it is difficult to obtain exact data for the off-grid PV sector these applications accounted for more than 90 % of Turkey's cumulative installed PV capacity of 5 MW by the end of 2009. PV systems are mostly used in stand-alone applications such as telecommunications base stations and solar lighting systems. Grid-connected PV systems are typically installed as demonstrations at research institutes and universities.

Turkey has an official goal of 30 % of electricity consumption from renewable energy by 2023. The proposed installed capacities of wind energy and geothermal energy are 20 GW and 600 MW respectively. An official figure is not quoted for solar electricity generation; however the Strategic Document of Electricity Energy Market and Security of Supply mentions that the huge solar energy potential is planned to be utilized in the coming years.

Following the announcement of plans to promote PV in Turkey by the Ministry of Energy and Natural Resources, a draft law defining feed-in tariffs for renewable energy sources (amending the Law on the Utilization of Renewable Energy Resources in the Generation of Electricity – 'Renewable Energy Law'), was accepted by the Industry, Commerce, Energy, Natural Resources, Information and Technology Commission of the Turkish Parliament in mid 2009 and submitted to the Turkish Parliamentary General Assembly. If the Assembly approves the amendments a highly competitive market is expected to emerge along the whole PV value chain in Turkey.

The Turkish PV Technology Platform (UFTP), comprising public bodies, universities, local authorities, trade and professional chambers and industrial companies, has outlined a roadmap for the PV sector in Turkey. The installed capacity of PV in Turkey in 2020 is forecast to range from 4 GW to 10 GW in the baseline and policy driven scenarios respectively.

The United Kingdom (GBR)
The annual installed PV capacity in the UK in 2009 was 7.08 MW, 1.6 times the growth of the previous year, and leading to a cumulative installed PV generation capacity of 29.6MW. In the UK the majority of PV installations are grid-connected distributed systems, installed on the roofs of domestic and non-domestic buildings.

Throughout 2009 the Low Carbon Buildings Programme (LCBP) provided grants to support installations of microgeneration technologies including PV for householders, community organizations, schools, the public sector and businesses. The programme was UK-wide and aimed to catalyse the installation of microgeneration in the UK to help create low carbon buildings. Under Phase 1 householders' PV installations were eligible for a maximum of 2 000 GBP/kW of installed capacity, subject to an overall maximum or 50 % of the relevant eligible costs, whichever was the lower. Phase 2 supported installations for community organizations, including schools. Both phases were closed to grant applications as of February 2010.

From April 2009 banding was introduced to the Renewables Obligation, providing differentiated levels of support to the various technologies in order to encourage a larger contribution from emerging renewable technologies. PV receives two Renewables Obligation Certificates per MWh generated.

It is expected that the changes to the Renewables Obligation and the introduction of a PV feed-in tariff (ranging from 0,293 GBP/kWh to 0,413 GBP/kWh) in 2010 will stimulate significantly increased demand for PV in the UK.

United States of America (USA)
Total PV capacity in the US increased by an estimated 473 MW in 2009 – representing growth in the annual market of about 40 % compared to the previous year. Of this market almost 92 % (433 MW) were grid-connected systems and a little over 8 % (40 MW) were off-grid installations. Cumulative installed capacity in the US reached almost 1 642 MW by the end of 2009.
Although the US economy was in turmoil and state legislatures faced severe budget crises in 2009, Federal and state leaders adopted policies to develop cleaner and more diverse energy sources as tools for economic revitalization. Coupled with falling prices for PV components, this contributed to an increase in PV capacity installed during the year compared to 2008. The Recovery Act, with its emphasis on clean energy as a way to stimulate the economy, prompted initiatives in nearly every agency of the Federal government.

Residential installed PV capacity more than doubled in 2009 in part due to the removal of the 2 000 USD cap on the investment tax credit. The 30 % federal investment tax credit for commercial and residential PV systems was extended to 2016 and can now also be used by electricity utilities. During 2009, 367 MW of grid-connected, distributed PV systems (158 MW residential, 209 MW non-residential) were installed. More than 33 000 systems

The 25 MW DeSoto Next Generation Solar Energy Center, Florida Power and Light 2009

were connected in 2009, compared to about 19 000 in 2008. California represented 49 % (212 MW) of the total increase in capacity for 2009 compared with 64 % in 2008, indicating increased growth in other states. Other prominent state markets included New Jersey (57 MW), Florida (36 MW), Colorado (23 MW) and Arizona (21 MW).

The largest utility-scale project connected to the grid in 2009 was the 28 MW DeSoto Next Generation Solar Energy Center in Arcadia, Florida. Commissioned by Florida Power and Light, it is the largest PV plant in North America and consists of 90 000 SunPower Corporation PV modules. Near Blythe, California, 24 MW of First Solar thin-film PV modules were commissioned in December 2009 and began delivering electricity to Southern California Edison. It is under contract to deliver 50 GWh of electricity per year for the next 20 years. All other PV plants installed in 2009 were smaller than 4 MW capacities.

Between September 2008 and September 2009, approximately 40 new solar incentive programmes were created in 19 states, and incentive levels in 10 states were reduced. Amongst the performance based incentives for PV in 2009 there were 14 production incentives (other than feed-in tariffs), 11 feed-in tariffs, and 14 renewable energy credit (REC) purchase programmes. California established a law, effective in 2011, that qualifies utilities purchasing electricity through the state's feed-in tariff as eligible for credits under the state's renewable portfolio standards (RPS). By the end of 2009, renewable portfolio standards existed in 29 states (plus Washington, D.C.). Sixteen of these states (and Washington, D.C.) have specified the amount of solar electricity and/or distributed generation that must be provided. New financing options have evolved rapidly at the city and county level. Through property-assessed clean energy (PACE) programmes, several local governments offered loans to property owners to help pay for PV systems. Several such programmes arose from the Department of Energy's Solar America Cities activities. By the end of 2009, 18 states had authorized and approximately 30 municipalities had established PACE programmes.

With about 100 MW of utility-scale projects operating at the end of 2009, US electricity utilities have announced more than 4,9 GW of large projects for the near future. PG&E and SCE alone plan to build and own 250 MW of PV over the next five years. More than 300 MW of this planned utility-scale construction could be connected in 2010. Electricity utility investments were also stimulated in 2009 by the income tax credit, which was not available to utilities in prior years. According to the Solar Electric Power Association (SEPA), innovative utility business models are emerging that include leasing rooftops from customers and mounting PV systems on poles in parking lots. Placing PV modules on power poles has allowed some utilities to monitor power quality while also adding generation to the distribution network.

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. China joined the IEA PVPS Programme in mid 2010, and it is anticipated that market and policy information will be reported in the future in similar fashion to other PVPS participating entities.

Belgium
292 MW of PV were installed during 2009, mostly in the region of Flanders. 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 5 MW to 6 MW of PV were installed during 2009, up from about 150 kW the previous year. Bulgaria has introduced an attractive feed-in tariff scheme, however concerns expressed about the annual degression mechanism appear to be leading to uncertainties for investors.

China
Although there are many plans for PV applications in China the actual domestic implementation of PV systems during 2009 is uncertain, with estimates of 160 MW to 220 MW installed during the year and a cumulative installed capacity of about 300 MW to 360 MW by the end of 2009.

During 2009 there were discussions about a feed-in tariff to support PV deployment in China. However only the province of Jiangsu (located on the east coast and the hub of China's considerable PV manufacturing resource base) introduced a feed-in tariff capped at 400 MW up to 2011 for three categories of systems: ground mounted at 2,15 CNY/kWh (about 0,315 USD/kWh), rooftop systems at 3,7 CNY/kWh and building integrated PV at 4,3 CNY/kWh. A reduction of the feed-in tariff over the first three years is foreseen but the actual overall binding period of the scheme appears uncertain.

In March 2009 the Ministry of Finance and Construction issued a call for large-scale roof-top applications and introduced the Golden Sun Programme, targeting at least 500 MW of PV over three years and including both grid-connected and off-grid applications. To date about 200 BIPV systems have been implemented and about ten utility-scale ground mounted systems, the largest with an installed capacity of 20 MW.

China's policies and strategies in support of PV operate at both the central government and local government/provincial levels. In the central government the main actors appear to be the National Energy Administration (NEA), the Ministry of Finance and Construction and the Chinese economic planning agency, the National Development and Reform Commission. The central government issues national targets and encourages the provinces to propose strategies to meet the targets; the provinces consequently start a bidding process with industry and other key market actors. In late 2009 the NEA raised the national goal of solar energy from 1,8 GW to 20 GW by 2020, with 5 GW to be installed by 2015. Of the 2020 target capacity of 20 GW more than 50 % are expected to be utility-scale PV systems.

Czech Republic
411 MW of PV were installed in the Czech Republic during 2009 due to favorable feed-in tariff conditions; estimates for 2010 are even higher. However, it is considered that such growth would be difficult to sustain due to the size of the country, the nature of the electricity system and ongoing political discussions about the support programme.

Currently the Czech Republic has 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. The tariffs are set by the Energy Regulatory Office (ERU), guaranteed for 20 years and funded by a levy on electricity consumer tariffs.

Greece
About 35 MW of grid-connected PV were estimated to have been installed in Greece during 2009. Greece has had a very attractive feed-in tariff scheme in operation since 2006 but the administrative burden has proved to be a formidable barrier to higher levels of PV deployment.

India
India is estimated to have installed about 30 MW of PV during 2009. 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. There is talk about a 20 year feed-in tariff scheme, but it appears that the Ministry of New and Renewable Energy (MNRE) has not yet determined a tariff and the overall funding of the National Solar Energy Mission is not clear. Further, the respective roles and responsibilities of the central and local governments are not well defined.

Slovenia
During 2009 the amount of installed PV capacity appears to have doubled from the 2 MW installed in 2008. In June 2009 Slovenia introduced a new 15 year feed-in tariff scheme with differentiated prices and an annual degression rate of 7 %.

Taiwan
During 2009 Taiwan installed about 7,7 MW of PV, mostly in the form of grid-connected roof-top installations. By the end of 2009 the cumulative installed PV capacity was about 11,8 MW.

Thailand
By the end of 2009 Thailand had a cumulative installed PV capacity of about 40 MW, with about 30 MW being off-grid systems. The annual market during 2009 was about 5 MW, mostly grid-connected systems.

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 0,25 USD/kWh) on top of the regular tariff of around 3 THB/kWh. The feed-in tariff is guaranteed for ten years. 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 more than 2,5 GW. As a consequence Thailand will probably reduce the additional payment to 6,5 THB in order to achieve a sustainable PV market growth rate.

Thailand plans to install the largest PV farm in Asia (around 70 MW installed capacity) with support from the Asian Development Bank under the very recent Asian Solar Energy Initiative.

1.4 R&D activities and funding

The public budgets for research and development in 2009 in the IEA PVPS countries are outlined in Table 4. Whereas the majority of countries are reporting some increase in 2009 expenditure compared to 2008, in aggregate R&D expenditure has stagnated. The most significant of the reporting countries in terms of expenditure remain the US, Germany, Korea and Japan. 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 activities in key countries is presented below.

The US is a clear leader in terms of R&D public funding for PV. Key to advancing PV technology is making the US Department of Energy (DOE) research and test facilities available to industry. In 2009, NREL installed an Atmospheric Processing Platform to work with industry to test novel thin film cells. The PV manufacturing industry can also work with NREL by making use of the Rutherford Backscattering System, which came on line in 2009, and to help design PV products for long life using the new Ultra-Accelerated Weathering System. Another channel of Recovery Act funds to PV research and development was the Advanced Research Projects Agency-Energy (ARPA-E), which supports high-risk, high-reward research. Further to the results of the DOE Renewable Systems Interconnection study published in 2008,

12 activities were initiated to develop advanced PV inverters, controllers for components and systems, and energy management systems for distributed PV systems. In 2009, five of these contractors were selected for additional funding to develop advanced hardware with communications and intelligence through to the prototype stage. Strategies for increasing solar energy use are being explored through the DOE Solar America Cities partnership with 25 US cities. Solar experts work with decision makers such as city councils, tax boards, and planning commissions to develop innovative solar financing options, streamline permitting processes, update build¬ing codes, and educate residents and businesses about solar energy. In 2009, DOE announced Recovery Act funding for 16 cities to implement 40 promising new projects. The DOE Solar Decathlon 2009 challenged 20 university teams from four countries to design and exhibit energy efficient houses powered by the sun.

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. Korean R&D funding in 2009 showed a 20 % increase over 2008 which in turn represented an almost three-fold increase over 2007 funding.

From 2008, Korea Energy Technology Evaluation and Planning (KETEP) has assumed the lead role in Korea's PV R&D programme. The government's R&D strategy is composed of four programmes: Strategic Technology Programme, Breakthrough Technology, Core Technology, and Demonstration and Planning Programme. Only Breakthrough Technology is led by

universities or research institutes. The other programmes are industry-led. The key programme is the industry-led Strategic Technology Programme, attracting a little over 50 % of the PV R&D budget.

In Japan, four PV projects under the control of the Ministry of Economy, Trade and Industry (METI) were conducted by the New Energy and Industrial Technology Development Organization (NEDO) – R&D of Next Generation PV Generation System Technologies, R&D of Common Fundamental Technologies for PV Generation Systems, Development of Technologies to Accelerate the Practical Application of PV Power Generation Systems, and R&D on Innovative Solar Cells. Other PV research included Photoenergy Conversion Systems and Materials for the Next Generation Solar Cells, Creative Research for Clean Energy Generation Using Solar Energy and Development of Organic PV toward a Low-Carbon Society. Major PV demonstration research projects implemented in FY 2009 covered topics such as field testing, grid stabilization, storage systems, islanding detection and international cooperative demonstrations. NEDO reviewed the PV Roadmap Toward 2030 (PV2030) to establish new R&D projects from FY 2010 and released a new roadmap, PV2030+, in June 2009.

Whereas there are no public funds made available for PV market stimulation in Norway, government PV funding, primarily for R&D, amounted to 91 million NOK in 2009 (up from 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 to 60 million NOK during 2009. 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.

2009 marked the third 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. Since the official launch of the Solar Europe Industry Initiative (SEII) in June 2010, the European Commission is adapting the FP7 budget to match the industry priorities identified in the report jointly prepared by the European Photovoltaic Industry Association and the European Photovoltaic Technology Platform. With public funding of up to 82 million EUR, the main areas of support within the FP7 2010 to 2011 calls will focus on manufacturing aspects of innovative cell designs and processes (thin films and wafer based technologies), optimization of manufacturing processes for concentrator PV and building integrated concepts for increasing the penetration of PV in the built environment.

Table 4 – Public budgets for R&D in 2009 in selected IEA PVPS countries

Country	Million EUR	Million USD
AUS	7,0	9,8
CAN	2,3	3,2
DEU	52,9	73,5
DNK	3,4	4,7
ISR	0,4	0,5
ITA	5,0	6,9
JPN (METI)	32,0	44,5
KOR	39,9	55,4
MEX	0,4	0,5
NLD	12,0	16,7
NOR	10,4	14,5
SWE	5,5	7,6
USA	104,4	145

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 2009. 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 2009 is presented in Table 5 and is directly based on the information provided in the national survey reports. This likely accounts for about one half of the worldwide production, the same as in 2008, and down from approximately two-thirds in 2007, about three-quarters in 2006 and at least 90 % previously.

Large and successful players in the PV supply chain are, by necessity, becoming increasingly multinational and vertically integrated in their operations. A prime example continues to be Norway's Renewable Energy Corporation (REC) which produces PV cells and wafers in Norway, silicon feedstock in the US, PV modules in Sweden, operates an integrated solar manufacturing complex in Singapore and has long-term supply agreements in place with other countries.

Amongst industry commentators a fairly consistent picture is emerging of the PV industry's future – fewer but larger businesses, global competition for resources and markets, increasing competition and price pressures at all levels of the value chain, and more professional and differentiated business models to address an increasingly sophisticated customer base. The global financial downturn and tighter access to investment capital have only served to accelerate these trends.

Table 5 – Reported production of PV materials, cells and modules in 2009 in selected IEA PVPS countries

Country ***(1)***	Solar PV grade Si feedstock production (tonnes)	Production of ingots & wafers (MW) ***(2)***	Cell production (all types, MW)	*Cell production capacity (MW/year)*	Module production (MW) ***(3)***		*Module production capacity (MW/year)*
					wafer based (sc-Si & mc-Si)	thin film (a-Si & other)	
AUS	–	–	12	*50*	12	–	*12*
AUT	–	–	7,5	*>15*	60,1	–	*na*
CAN	>182 ***(4)***	–	0,3	*~*	42	0,3	*>106*
CHE		195	>0,8	*40*	>2,2	>0,8	*>40*
DEU	18 400	1 347	2 456	*3376,2*	1 765	791	*3140*
DNK	–	1	–	–	1	–	*1*
ESP	–	–	23	*260*	269	–	*1 061*
FRA	–	127	na	*na*	na	na	*211*
ITA	–	–	66,1	*200*	163,5	–	*478*
JPN	>4 900	>>566	1 487	*2 038*	1 058	206	*>>1317*
KOR	9 900	>440	231	*740*	365	14	*975*
MEX	–	–	–	–	>>1,7	na	*265*
MYS	–	–	na	*1448*	–	na	*848*
NOR	na	>582	na	*250*	–	–	–
PRT	–	–	5,5	*7*	54	5,5	*131*
SWE	–	–	–	–	173	–	*251*
TUR	–	–	–	–	20	–	*43,5*
USA	31 476	396	na	*na*	471	307	*na*

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. Industry data from the UK were not available.
(2) Assuming 12 tonnes of ingot equivalent to 1 MW of PV cells
(3) mc-Si (multicrystalline silicon) includes modules based on EFG and String Ribbon cells. 'Other' refers to technologies other than silicon based. The total module production and module production capacity data for some countries were not available.
(4) Plus 125 metric tonnes Cadmium Telluride production that is exported for the fabrication of thin-film CdTe modules

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

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 focuses on the wafer-based production pathway. Although some IEA PVPS countries are reporting on production of feedstock, ingots and wafers, the picture from the national survey reports of these sections of the PV industry supply chain is not complete and consequently this section is provided more as background information.

Feedstock

The main source of silicon feedstock for PV cells is virgin polysilicon. The process is the same as for producing semiconductor grade silicon. However, the producers have simplified some steps in their processes for supplies to the PV industry. There are many attempts to replace the current expensive purification process, based on chemical gaseous purification, by cheaper alternatives including metallurgical purification (condensed phase). Although significant progress has been achieved during recent years and several pilot plants have been put into operation, these new materials have not yet been introduced to the market.

In 2009 solar photovoltaic grade silicon feedstock supply was dominated by the three previous major producing countries – Germany, the US and Japan – plus Korea is now also reporting significant production. Production in the US (the largest producer by far) increased by over 20 % compared to 2008, with Hemlock Semiconductor Corporation, Renewable Energy Corporation and MEMC together accounting for almost 94 % of US production, of which 90 % was exported (compared to 85 % the previous year). The US provided about half the solar photovoltaic grade silicon feedstock used in the IEA PVPS countries. The reported price of solar photovoltaic grade silicon feedstock decreased by about 7 % from 2008 to 2009 indicating increased worldwide competition in the industry and a more healthy demand/supply situation than existed in previous years.

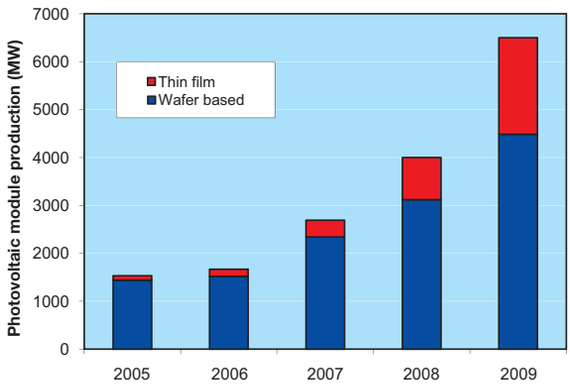


Figure 4 – Trends in photovoltaic module technologies in the IEA PVPS countries 2005–2009

The key production countries have reported new entrants preparing to enter the market. Many other newcomers (for example, numerous companies in China alone) have also announced plans to enter the feedstock silicon business. However some potential entrants are expected not to proceed due to a limited availability of venture capital.

Ingots and wafers

To make single crystal silicon ingots, multicrystalline silicon ingots or multicrystalline silicon ribbons the basic input material is highly purified silicon. The ingots need to be cut into bricks or blocks and then sawn into thin wafers, whereas the ribbons are cut directly to wafers of desirable size. Silicon ingots are of two types: single crystal and multicrystalline. The first type, although with different specifications regarding purity and specific dopants, is also produced for microelectronics applications, while multicrystalline ingots are only used in the PV industry. Ingot producers are in many cases also producers of wafers.

Norwegian, German, Korean and Japanese companies feature most prominently in this section of the industry value chain. Other countries reporting activities include Switzerland, Denmark, France, Britain and the US. Some companies are vertically-integrated, controlling the process from ingots to cells and modules. Norway's REC Wafer has external customers including Chinese, Japanese, British and German companies. Japan's Kyocera manufactures silicon ingots and wafers for its own use. The UK's Crystalox Limited is one of the world's largest producers of multicrystalline silicon ingots, exporting to PV companies in Europe and Japan.

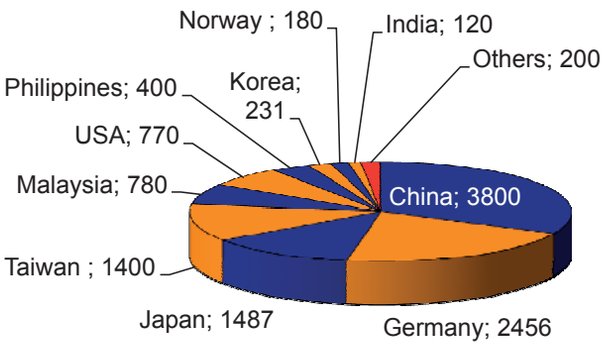


Figure 5 – Estimated world PV cell production (MW) by country in 2009

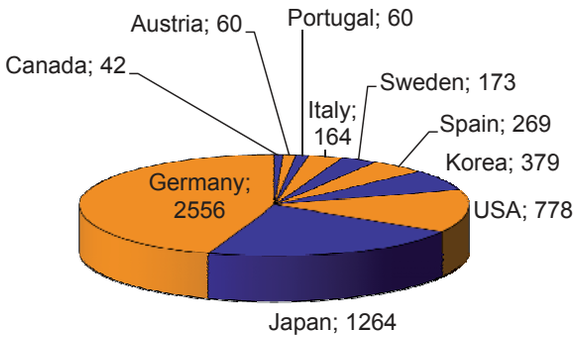


Figure 6 – PV module production (MW) by IEA PVPS country in 2009

2.2 Photovoltaic cell and module production

The total PV cell production volume for 2009 in the IEA PVPS countries is estimated to be about 6 000 MW, up from more than 3 740 MW in 2008, an increase of over 60 %. Germany's production increased by an impressive 62 % while Japan's production increased by 21 %. Between them these two countries account for two thirds of the IEA PVPS countries' PV cell production. Other major PV cell producing countries include Korea, Malaysia, Norway and the US.

It is estimated that global PV cell production exceeded 11,5 GW in 2009, almost twice the production of the IEA PVPS countries alone. In particular, reports suggest production of 3 800 MW in China, 1 400 MW in Taiwan, 400 MW in the Philippines and 120 MW in India. 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.

Germany clearly maintained its position as the leading producer of photovoltaic modules amongst the IEA PVPS countries during 2009. Production of modules in this country accounted for almost 40 % (up from 22 % in 2008) of the IEA PVPS countries' production, with Japan in second place with almost 20 % (the same as in 2008). In the United States, the third largest PV module producing country, production increased by over 80 % from 2008.

Spain's module production almost halved from 2008 to 2009 reflecting that country's market turmoil. Significant module production increases were reported in Canada, Korea and Portugal. Malaysian thin film production took off during 2009, Germany's thin film production increased from just under 300 MW to almost 800 MW, US output of thin film technologies increased by 15 %, while Japanese thin film production doubled relative to 2008. Thin film production in the IEA PVPS countries accounted for over 30 % of module production in 2009, up from 22 % in 2008, 13 % in 2007 and 9 % in 2006. Total IEA PVPS country module production increased by over 60 % from 2008, following growth of about 50 % in each of the previous two years. To complete the picture, in 2009 China exported almost 4 GW of modules (about the same amount of PV that was installed in Germany during the year) and the annual module production capacity in India is estimated to be 500 MW to 700 MW.

The cell production capacity in the IEA PVPS countries, defined as the maximum output of manufacturing facilities, increased by about 54 %. Utilization of capacity was about 65 %, similar to the previous four years and down from a high of 86 % in 2004. Module production capacity increased by close to 50 % and the utilization of capacity was also close to 65 %. 2009 provided some interesting growth stories in individual countries and also at the global level. The reader is directed to the individual national survey reports for a comprehensive summary of manufacturers and production in each of the countries.

Some common themes identified in previous years can be updated in 2009:

- cell supply shortages that created difficult circumstances for some module producers have eased;
- foreign product and price offers are continuing to impact domestic markets, and now also industries themselves;
- access to a booming foreign market still provides an ongoing lifeline for the industries in some countries where the domestic market had slowed appreciably;

PV on a Swiss Farmhouse.

- and further, it would appear that a large inventory of PV products emerged during 2009 (global demand of 7 GW compared with supply of over 11 GW) which should continue to exert downward pressure on prices in the near-term.

Over the last decade or so in the IEA PVPS countries, each year's installed market capacity expressed as a percentage of total module production has ranged from 59 % in 1998 to 91 % in 2004. In 2009 the installed market capacity in these countries as a percentage of module production was about 95 %. The only exception to this relationship was in 2008 when installed market capacity in the IEA PVPS countries exceeded module production by more than 50 %.

Amongst the key PV production countries there were a number of interesting developments and news stories during 2009, a year otherwise remembered for global economic difficulties. The German foreign trade and inward investment agency, Germany Trade & Invest, listed a total of 70 companies involved in PV production in 2009, creating a turnover of 8,6 billion EUR. Further, 62 PV equipment manufacturers supplied tools for every step of the PV value chain and generated an additional turnover of two billion EUR. The development of the inverter industry is another success story. By the end of 2009 around 63 000 workers were employed in handcraft and trade companies in the German PV industry.

In Japan a number of businesses enhanced their PV-related activities or entered a variety of PV-related sectors. In the area of silicon feedstock and wafer manufacturing, some PV players enhanced their production capacity, expanded businesses in overseas markets and advanced their entry plans. A Japanese manufacturer plans to construct a new plant as a joint venture with a European partner and a Taiwanese manufacturer acquired a Japanese manufacturer. Regarding PV cell manufacturing, some parties announced plans to increase their production capacity to the GW level. A manufacturer announced plans to manufacture thin film silicon PV modules in a joint venture with a petroleum company. Some manufacturers began manufacturing PV modules, and some Chinese manufacturers started entering the Japanese market. A number of manufacturers new to PV have entered the PV components market. Power source manufacturers started development of large-sized power conditioners and heavy electric machinery manufacturers have entered the MW-scale PV power generation business. In the area of manufacturing equipment for PV cells, manufacturers have developed sales alliances with overseas manufacturers and increased their production capacity.

In the US, the Recovery Act provided a new 30 % investment tax credit for projects that establish, re-equip, or expand manufacturing facilities. Although relatively few manufacturers received these funds during 2009, about one billion USD were awarded by early 2010. More new PV manufacturing plants in the US were announced in the first half of 2009 than in the previous three years combined. Companies based in Europe and Asia showed increased interest in US-based PV manufacturing. On the other hand, a number of companies announced lower profits, layoffs, and delayed plans for expansion. Recession forced some companies to re-evaluate their business plans. In another response to a challenging market, some manufacturers decided to buy unfinished PV farm projects and complete them with their own products, thereby creating demand for the product.

During 2009 Korean PV production covered the whole value chain, with a focus on upstream sectors. One company produced a significant amount of solar PV grade Si feedstock and nine companies were involved in silicon ingot and wafer production. Six companies

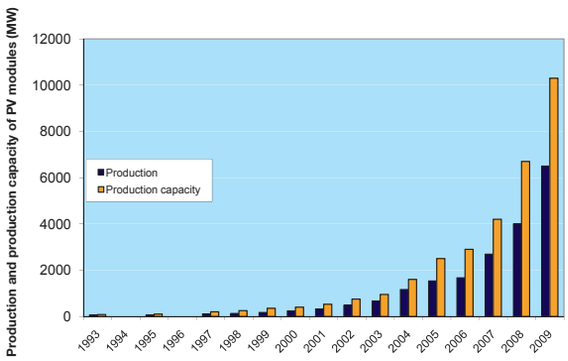


Figure 7 – Yearly PV module production and production capacity in the IEA PVPS reporting countries

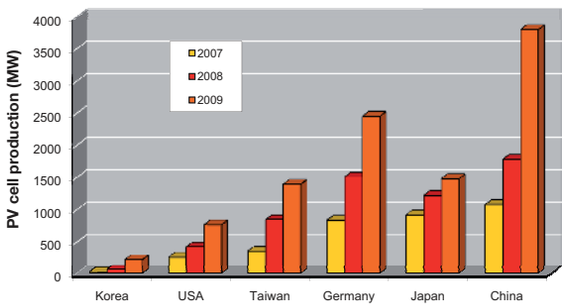


Figure 8 – Evolution of the PV industry in selected countries – cell production 2007, 2008 and 2009

produced PV cells; eleven companies produced crystalline silicon PV modules; and two companies produced a-Si thin film PV modules. By the end of 2009 in Malaysia, there were four major foreign direct investments (FDIs) in PV manufacturing. In late 2009, First Solar announced an additional eight production lines at its manufacturing facility in Kedah which will increase capacity to almost 1,3 GW. During 2009 in Norway, REC Wafer's plants, with about 950 employees, produced about 582 MW of multicrystalline and single crystal wafers. REC Solar, with about 150 employees, increased its PV cell production capacity to 250 MW. Elkem ASA, a world leading supplier of metallurgical grade silicon, is increasingly becoming an important actor in the PV value chain through its division Elkem Solar. The plant was commissioned in 2008 and production ramped up during 2009. Total capacity is about 6 000 tonnes Si and the plant has 260 employees. NorSun AS produces single crystal silicon ingots from high purity grade (>99,9999 %) silicon raw material. NorSun operates a manufacturing plant with a capacity of 200 MW and employs about 200 people.

2.3 *Balance of system component manufacturers and suppliers*

From a cost perspective, balance of system (BOS) components account for between 20 % (standard grid-connected system) and 70 % (off-grid installation) of the total PV system costs. 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. In this field, the following main trends could be observed during 2009:

- Multi-functional PV inverters: With Smart Grid pilot projects under way in several countries such as the US, Germany, Japan and Australia new inverters are currently being developed which sophisticated monitoring, communications and control abilities. With the help of these devices, the electricity grid operators can monitor and control the PV plants to actively support grid management, for example by providing reactive power or backup capacity. This development is also supported by new grid codes, which have been introduced in a number of countries, such as Germany and the US.

- Micro-inverters (AC-Modules): Micro-inverters are gaining acceptance, mainly for residential and small commercial applications. These units simplify system design and installation and can help to increase energy yield, especially for building integrated PV installations which often suffer from losses due to partial shading. The main manufacturers of micro-inverters include US-based Enphase Energy, Tigo Energy, Solar Edge and others.

In Europe the large inverter companies are located in Germany, Spain, Austria, Switzerland, Denmark, and Italy. Outside Europe activities in this field are reported from Japan, the US, Canada and Korea. Prices quoted in National Survey Reports for 2009 range from 0,18 EUR per W for large inverters up to 0,45 EUR per W for smaller units. On the one hand, increased production and new market players are supporting the price reduction of the products. However, ongoing high demand as well as shortages on the supply side are still leading to long lead times for delivery.

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.

In addition to basic BOS components, the 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. Activities in this field are reported from most of the IEA PVPS countries.

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 2009 the lowest system prices in the off-grid sector, irrespective of the type of application, typically ranged from about 8 USD/W to 12 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 10 USD/W, about 15 % less than the corresponding average price reported for 2008.

The lowest achievable installed price of grid-connected systems in 2009 also varied between countries as shown in Table 6. The average price of these systems was 4,8 USD/W, more than 30 % lower than the 2008 price. Prices as low as 3,5 USD/W were reported but typically prices were in the range 4 USD/W to 6 USD/W. Large grid-connected installations can have either lower system prices depending on the economies of scale achieved, or

Table 6 – Indicative installed system prices in reporting countries in 2009

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	**8,4–14,0**	11,7–19,5	**8,4–11,2**	11,7–15,6	**4,0–5,6**	5,6–7,8	**3,4–5,6**	4,7–7,8
AUT	**6–15**	8,3–20,8	**6–15**	8,3–20,8	**4,3–5,1**	6,0–7,1	**3,8–5,5**	5,3–7,6
CAN	**10,1**	14,0			**5,4**	7,5		
CHE	**8,4**	11,7	**7,6**	10,5	**5,3–5,8**	7,3–8,1	**3,7–4,8**	5,1–6,7
DEU					**3,0–4,3**	4,2–6,0	**2,8–3,8**	3,9–5,3
DNK	**5,4–8,1**	7,5–11,2	**10,7–16**	14,9–22,2	**2,7–5,4**	3,7–7,5	**2,7–6,7**	3,7–9,3
ESP					**3,2–4,5**	4,4–6,2	**3–4,2**	4,2–5,9
FRA					**5–5,5**	6,9–7,6	**2,5–4,5**	3,5–6,3
GBR					**6,5–7,2**	8,4–9,0	**6,3–7,1**	8,1–8,7
ISR					**2,6–4,2**	3,6–5,9	**2,6–4,2**	3,6–5,9
ITA	**8–10**	11,1–13,9			**4–5**	5,6–6,9	**3–4,5**	4,2–6,3
JPN					**4,8**	6,6	**4,2**	5,8
KOR					**3,3–4,2**	4,6–5,9	**4,5**	6,2
MEX	**5,8**	8	**8,6**	12	**5,8**	8	**4,7**	6,5
MYS					**4,5**	6,2	**4,5**	6,2
NOR	**11,4–34,3**	15,9–47,7			**6,8–9,1**	9,5–12,7		
PRT			**8,0–10,0**	11,1–13,9	**5,0–6,0**	6,9–8,3	**4,0–5,0**	5,6–6,9
SWE	**7,6**	10,5			**7,1**	9,9	**4,4**	6,1
TUR	**5–6**	6,9–8,3	**5–5,5**	6,9–7,6	**3–3,5**	4,2–4,9	**3**	4,2
USA					**4,0–6,1**	5,6–8,5	**2,5–3,6**	3,5–5

Notes: Additional information about the systems and prices reported for most countries can be found in the various national survey reports on the IEA PVPS website. Excludes VAT and sales taxes. More expensive grid-connected system prices are often associated with roof integrated slates or tiles or one-off building integrated designs or single projects, and figures can also relate to a single project.

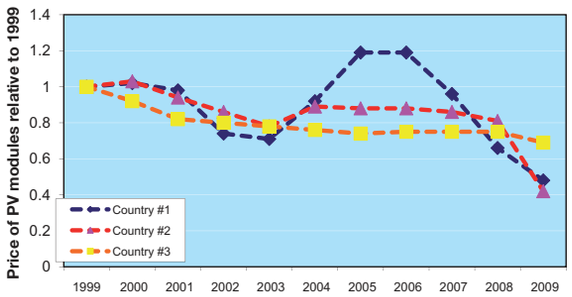


Figure 9 – Evolution of price of PV modules in selected reporting countries accounting for inflation effects – Years 1999–2009 (Normalized to 1999)

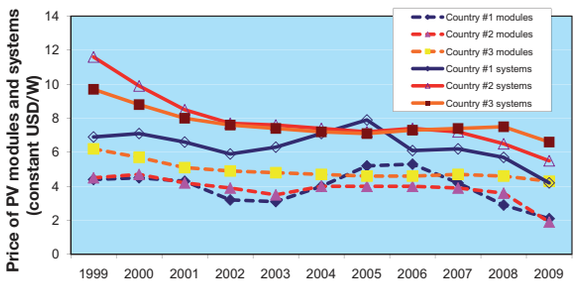


Figure 10 – Evolution of price of PV modules and small-scale systems in selected reporting countries accounting for inflation effects – Years 1999–2009

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. The reason behind the larger falls in grid-connected system prices (compared with off-grid systems) is the relatively larger impact of the module price reductions (discussed below).

On average, the cost of the PV modules in 2009 (shown in Table 7) accounted for 54 % of the lowest achievable prices that have been reported for grid-connected systems. In 2009 the average price of modules in the reporting countries was about 2,6 USD/W, a decrease of 35 % compared to the corresponding figure for 2008. Most but not all reporting countries recorded significantly lower module prices than in 2008. Whereas four countries reported module prices less than 2 USD/W, more than 55 % of the lowest achievable prices fell within the range of 2 USD/W to 3 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

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

Country	Currency	2009		
		national currency	EUR	USD
AUS	AUD	3–6	1,7–3,4	2,3–4,7
AUT	EUR	2,2–2,3	2,2–2,3	3,0–3,2
CAN	CAD	3,31	2,1	2,9
CHE	CHF	3,3–3,8	2,2–2,5	3,0–3,5
DEU	EUR	1,5–2,5	1,5–2,5	2,1–3,5
DNK	DKK	15–25	2,0–3,4	2,8–4,7
ESP	EUR	1,2–2,5	1,2–2,5	1,6–3,5
FRA	EUR	1,1–2,0	1,1–2,0	1,5–2,8
ISR	NIS	14–20	2,6–3,7	3,6–5,1
ITA	EUR	1,6–2,2	1,6–2,2	2,2–3,0
JPN	JPY	402	3,1	4,3
KOR	KRW	2400–2600	1,4	1,9–2,0
MEX	MXP	54–67,5	2,9–3,6	4–5
MYS			2,7	3,71
PRT	EUR	1,5–3,0	1,5–3,0	2,1–4,2
SWE	SEK	18–50	1,7–4,7	2,4–6,5
TUR	TRY	4,3–6,5	2,0–3,0	2,8–4,2
USA	USD	1,85–2,2	1,3–1,6	1,85–2,2

Notes: Current prices. Excludes VAT and sales taxes.
ISO currency codes are outlined in Table 14.
Single figures generally refer to 'typical' module prices; where there is a range in the figures presented for a given country, the lower value generally represents the lowest price achieved & reported (often for a large order) whereas a significantly higher figure can refer to special products, roof tiles etc.
Details are contained in the individual national survey reports.

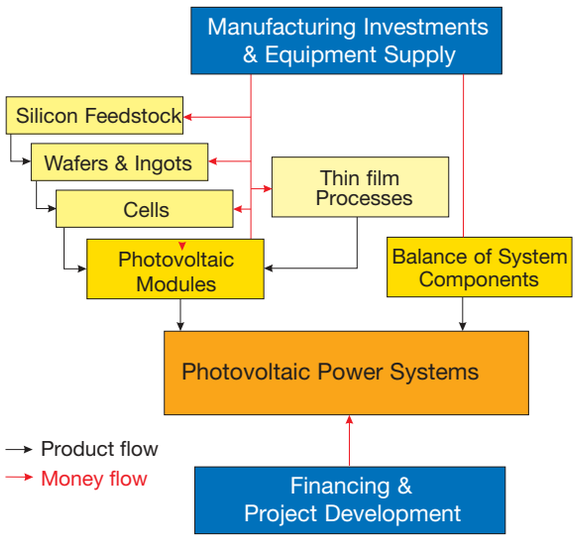


Figure 11 – Photovoltaic (PV) industry supply chain

along the PV industry supply chain. Export activities played an important role in many countries in 2009 – 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 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 2009 amongst the IEA PVPS countries approached 30 billion USD, maybe 25 % down on the previous year. This is because the annual market was much the same size as in 2008 but prices had decreased considerably as presented in section 2.4.

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 of about 187 000 persons across research, manufacturing, development and installation, with steady annual increases in the reporting countries. The exception has been Spain which suffered severe job losses in 2009 as a result of the collapse of the market (and the businesses without export potential). If the Spanish situation is not included, the figures reported for 2009 represent an increase approaching 30 % compared to the 2008 figure. Although less significant, manufacturing companies in many countries have continued to benefit from the continuing strong level of demand within Germany. The strong market growth in a number of countries (see Table 3) means that the risks to business of relying on single markets have diminished. However, at the same time, new business risks are 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 market growth.

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

Country	Research, development, manufacturing and deployment labour places
AUS	5 300
AUT	2 870
CAN	2 700
CHE	8 100
DEU	65 000
DNK	350
FRA	8 470
GBR	1 171
ITA	8 250
JPN	26 700
KOR	6 500
MEX	119
MYS	3 172
NOR	1 485
SWE	630
TUR	300
USA	46 000

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 2009 can be found in Table 9. Specific details about many of these measures can be found in section 1.3 of this report and further details are available in the relevant national survey reports, available from the IEA PVPS website. A brief outline of the measures is given the following box.

Over the previous five years the number of countries offering feed-in tariffs (FiT) for PV electricity has more than trebled. The country descriptions contained in section 1.3 of this report provide an overview of a number of FiT approaches operating in 2009 in different countries – from those that have driven grid-connected PV investments in large-scale (multi-MW) plants (for example in Korea, Portugal and Spain), to those that favour smaller-scale building-integrated applications (for example in Australia, Switzerland, France, Israel and Japan), and to combinations of both approaches (for example in Canada, Italy and the US). The FiT can be national-scale, state-based or even operate at the local community level, such as the Swedish scheme announced in 2009.

The FiT is clearly seen as the prime mechanism for promoting strong growth in grid-connected PV applications, as reinforced by the significant increases in the 2009 annual PV markets (table 3) of countries such as Australia, Austria, Canada, Switzerland,

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

Germany, France, Italy, Israel, and the Netherlands. The healthy market growth in both Japan and the US is due to other factors (see section 1.3) but is being reinforced by newly developed feed-in tariff mechanisms. The decrease in the 2009 annual markets of both Korea and Portugal (and notably Austria and the Netherlands in previous years) shows the influence of adjustments to feed-in tariff schemes. The almost-total collapse of the Spanish PV market in 2009, following the super-explosive growth of that market in 2008 with investment driven by a generous feed-in tariff, has been a salutary reminder of the risks associated with politically-driven markets.

There is now a wealth of information available worldwide to policymakers regarding the impacts of various designs of feed-in 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. Probably one of the key messages from the successful German FiT experience – and this scheme also has 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. While fewer measures are likely to incur a lower administrative burden, on the other hand more measures may mean

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	•	•	•	•		•	•	•	•	•	•	•			•		•	•(2.)		•
Direct capital subsidies	•	•		•		•		•		•	•	•		•				•		•
Green electricity schemes	•	•	•	•		•	•			•	•									•
PV-specific green electricity schemes	•	•		•																•
Renewable portfolio standards (RPS)	•										•	•(3.)						•		•
PV requirement in RPS																				•
Investment funds for PV			•			•	•					•								•
Tax credits			•	•				•			•			•			•			•
Net metering	•	•	•	•	•					•			•	•						•
Net billing			•	•		•					•			•						•
Commercial bank activities	•					•			•		•				•				•	•
Electricity utility activities	•		•	•	•	•	•				•									•
Sustainable building requirements	•		•	•	•	•	•					•					•		•	•
Indicative household retail electricity price USD cents (1.)	10,2–15,6	26,4	6,1	14,7	37,5	31,5			12,5	23,6	19,1–25,8	13,3–19,6	up to 36,2	up to 13,5		11,1–14,3	10,3–19,2	18,3–20,9	18,0	10,4

Notes:
1. *Typical residential kWh price expressed in USD cents (1 USD/100), including all taxes but not including variations due to time of use, total electricity consumption or any fixed rates*
2. *Local, community-based scheme*
3. *Demonstration programme*

greater flexibility to deal with unforeseen circumstances. Funding issues are significant and funding continuity is critical to the success of any mechanism.
It could be argued that PV technology can now be regarded as mainstream in many of the countries with expanding PV markets, and that the main policy challenge is to decide how best to move towards true market transformation. At some point in the near future, probably within the next decade, the sustainable market may eventuate with the arrival of grid parity (discussed in the next section). The current strongly growing grid-connected PV market relies (almost entirely) on a model of ever increasing amounts of public funds and large doses of political goodwill. Payments made for PV electricity today under various feed-in tariff schemes are skyrocketing. The issue 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. It will become increasingly important to understand why (or indeed why not) customers invest in PV or purchase PV electricity – to date very few mechanisms have

Table 10 – Characteristics of some key support measures

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

explored willingness to pay for PV, except perhaps the Malaysian bidding scheme and the Swiss solar stock exchanges.

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

3.2 Indirect policy 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 being implemented by a number of governments to increase renewable energy deployment in their countries. A number of countries experiencing difficulties in implementing a carbon price through an emission trading scheme or a carbon tax see the RPS approach as a more politically acceptable approach to climate change policy.

In its simplest form, the RPS is unlikely to have a positive impact on PV deployment as the general requirement for renewable energy may simply encourage the lowest direct cost renewable energy options (and not PV) for consideration. In the US a number of PV-specific regulatory approaches, such as PV set-asides, have been developed. Other countries (for example Australia, Japan and the UK) have refined their RPS approaches in ways that will benefit PV. One method is to allow PV electricity to earn multiple certificates (the currency of the RPS) compared to other renewable technologies, with the multiplier able to be varied over time to reflect the increasing cost-competitiveness of PV electricity. 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. The implications for PV deployment range from modest where, for example, PV is included in a suite of options for reducing the building's energy foot print, to dramatic where PV is specifically mandated as an inclusion in the building development.

Grid parity is the term that is used to describe the rapidly-approaching point in time when the cost of electricity from PV systems matches the price paid by consumers for retail electricity. It is thought that grid parity will lead to a new, strong growth in consumer demand for PV within a truly sustainable market no longer requiring government support. The decrease in PV system prices has already been discussed (section 2.4). In many countries the retail electricity price has increased substantially in recent times and, more importantly, further large increases have been flagged for the near future. Anecdotal evidence suggests that these price increases – real and implied - are driving a heightened interest in PV amongst many consumers.

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, driven by both government mandates and business opportunities (section 1.3). 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. In the US and Italy, for example, electricity utilities are already actively exploring a range of business models for their involvement with PV.

A recent survey by IEA PVPS member the Solar Electric Power Association (SEPA), together with Gartner Research, sought to understand the needs and motivations for involvement in PV amongst 134 electricity utilities in Europe and the US. National policy settings are seen as the key driver for electricity utility involvement in PV. In Europe, the state or regional governments play an important secondary role, while in the US the public utility commission or regulator is the second major factor. Already a significant number of electricity utilities have experience with ownership of PV plant (36 % of respondents), and a wide experience with contracting mechanisms such as feed-in tariffs and power purchase agreements considerably extend utilities' familiarity with solar electricity. There is a great variety of internal management approaches to the question of procurement of electricity utility solar resources but partners with specific PV solar system experience are rated highly, paralleling recent efforts by the PV industry to develop utility-scale project development businesses.

As the PV market matures and opportunities for business are identified, various non-utility commercial initiatives have emerged (for example in Australia, Germany, Israel, Japan, the Netherlands, Turkey and the US). These include activities such as preferential home mortgage terms and green loans from commercial banks, share offerings in private PV investment funds and other schemes.

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 2009, 80 IEC International Standards and Technical Specifications (including versions in different languages) had been published covering a comprehensive range of issues. Currently 32 countries are active participants in TC 82 and a further 13 have observer status, with three more countries joining in 2009.

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 2009 TC 82 has published the following new or revised IEC standards or Technical Specifications (TS):

- IEC 60891 (2009-12) Ed. 2.0, Photovoltaic devices – Procedures for temperature and irradiance corrections to measured I-V characteristics
- IEC 60904-4 (2009-06) Ed. 1.0 Photovoltaic devices – Part 4: Reference solar devices – Procedures for establishing calibration traceability
- IEC 60904-10 (2009-12) Ed. 2.0 Photovoltaic devices – Part 10: Methods of linearity measurement
- IEC 62446 (2009-05) Ed. 1.0 Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection

Important work items currently high on TC 82's priority list include, amongst other things, concentrator photovoltaic (CPV) modules and assemblies, the qualification of the Safety of PV power converters, charge controllers and other DC equipment for PV systems (such as, for example, combiner boxes).

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 2009, two new EN standards were published:

- EN 50513:2009 Solar wafers – Data sheet and product information for crystalline silicon wafers for solar cell manufacturing
- EN 50524:2009 Data sheet and name plate for photovoltaic inverters.

In the US standardization focuses on safety and interconnection issues of PV systems. Technology acceptance activities of the DOE PV programme included the creation of the Solar America Board of Codes and Standards (SolarABCs), which is designed to improve the development of codes and standards that facilitate the installation of safe, high-quality PV systems. In addition, US representatives also actively participate in the IEC TC 82.

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

Following the enormous growth of grid-connected PV and the installation of utility scale PV systems, full integration of PV systems into grid operation is now becoming more and more critical. This development is supported by new grid codes that allow PV plants to actively contribute to grid management and thus enable a considerably increased capacity to be connected to the distribution systems.

4 Summary of trends

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

- About 6,2 GW of PV capacity were installed in the IEA PVPS countries during 2009 (much the same amount as in the previous year) which brought the total installed capacity to 20,4 GW. By far the greatest proportion (74 %) was installed in Germany and Italy alone. If the US, Japan and France are also included, then over 93 % of PV installations in 2009 occurred in five countries.

- Growth of the annual market was evident in a number of countries. The Israeli market took-off with an eighteen-fold increase while the Canadian market experienced a nine-fold boost – both driven by new and successful feed-in tariff schemes. A number of countries experienced an annual market increase of the order of two to four-fold – Australia, Austria, Switzerland, Germany, France, Italy, Japan and the Netherlands. The US annual market experienced 40 % growth. While annual growth decreased somewhat in both Korea and Portugal in 2009, in both cases 2008 represented large spikes in the PV capacity installed during the year. Compared to the 2007 annual markets, both Korea and Portugal enjoyed strong growth rates in 2009. In contrast the Spanish annual market almost totally collapsed in 2009 (to around 2 % of the 2008 market size and even less than the amount of PV installed back in 2006).

- Grid-connected applications dominated in the reporting countries (about 99 % of the 2009 market) but the largely unsubsidized off-grid markets continued to grow worldwide, albeit less vigorously than the publicly funded grid-connected PV markets.

- Whereas the majority of countries are reporting some increase in 2009 expenditure compared to 2008, in aggregate R&D expenditure has stagnated. The most significant of the reporting countries in terms of expenditure remain the US, Germany, Korea and Japan. The US is a clear leader in terms of R&D public funding for PV.

- In 2009 solar photovoltaic grade silicon feedstock supply was dominated by the three major producing countries – Germany, the US and Japan – plus Korea is now reporting significant production. Production in the US (the largest producer by far) increased by over 20 % compared to 2008, with four active manufacturers exporting about 90 % of production. European (particularly Norway, Germany and the UK), Japanese, Korean and US companies feature most prominently in the ingot and wafer section of the PV industry value chain. In Europe the large inverter companies are located in Germany, Spain, Austria, Switzerland, Denmark, and Italy. Outside Europe activities in this field are reported from Japan, the US, Canada and Korea.

- The total PV cell production volume for 2009 in the IEA PVPS countries was estimated to be about 6 000 MW, up from more than 3 740 MW in 2008, an increase of 60 %. The largest increase in production took place in Germany (up by 62 %) while Japan's production increased by 21 %. Between them these two countries account for two thirds of the IEA PVPS countries' PV cell production. Global PV cell production was about twice the production of the IEA PVPS countries alone.

- Total IEA PVPS country module production increased by over 60 % from 2008, following growth of about 50 % in each of the previous two years. Germany clearly maintained its position as the leading producer of photovoltaic modules amongst the IEA PVPS countries during 2009. Production of modules in this country accounted for almost 40 % (up from 22 % in 2008) of the IEA PVPS countries' production, with Japan in second place with almost 20 % (the same as in 2008). In the United States, the third largest PV module producing country, production increased by over 80 % from 2008. Spain's module production almost halved from 2008 to 2009 reflecting that country's market turmoil. Significant module production increases were reported in Canada, Korea and Portugal. To complete the picture, in 2009 China exported almost 4 GW of modules (about the same amount of PV that was installed in Germany during the year).

- Thin film production took off during 2009, particularly in Malaysia, Germany, the US and Japan. Thin film production in the IEA PVPS countries accounted for over 30 % of module production in 2009, up from 22 % in 2008, 13 % in 2007 and 9 % in 2006.

- The following themes can be applied to the PV industry in 2009. Cell supply shortages that created difficult circumstances for some module producers have eased. Foreign product and price offers are continuing to impact domestic markets and now also industries themselves. Access to a booming foreign market still provides an ongoing lifeline for the industries in some countries where the domestic market had slowed appreciably. Large and successful players in the PV supply chain are,

by necessity, becoming increasingly multinational and vertically integrated in their operations. It would appear that a large inventory of PV products emerged during the year.

- On average, the cost of the PV modules in 2009 accounts for 54 % of the lowest achievable prices that have been reported for grid-connected systems. In 2009 the average price of modules in the reporting countries was about 2,6 USD/W, a decrease of 35 % compared to the corresponding figure for 2008.

- The average lowest achievable installed price of grid-connected systems in 2009 was 4,8 USD/W, more than 30 % lower than the 2008 price. Prices as low as 3,5 USD/W were reported but typically prices were in the range 4 USD/W to 6 USD/W. System prices for the lowest price off-grid applications are about double those for the lowest price grid-connected applications.

- The total value of business in 2009 amongst the IEA PVPS reporting countries approached 30 billion USD (22 billion EUR). In parallel with the business value of PV production and markets, the economic value in the IEA PVPS countries can be characterized by the total direct employment of about 187 000 persons across PV research, manufacturing, development and installation.

- 2009 clearly reinforced the notion that the feed-in tariff (FiT) approach is currently the prime mechanism for promoting strong growth in grid-connected PV applications. Over the previous five years the number of countries offering feed-in tariffs for PV electricity has more than trebled. Across the IEA PVPS countries a number of other key PV support measures also exist and have demonstrated success. Two broader issues are particularly relevant to the future market for grid-connected PV – climate change policy deliberations and the role of electricity utilities.

Table 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	5 148	37	5 683	34
2007	663	24	7 356	43	8 019	41
2008	741	12	13 452	83	14 193	77
2009	837	13	19 543	45	20 381	44

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
Power installed during year in IEA PVPS reporting countries (MW)	371	481	1 058	1 367	1 440	2 336	6 174	6 188
Module production during year in IEA PVPS reporting countries (MW)	482	667	1 160	1 532	1 668	2 690 *(estimate)*	4 000 *(estimate)*	6 500 *(estimate)*

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

Australia	AUS	Muriel Watt & Joe Wyder, IT Power Australia, for the Australian PV Association
Austria	AUT	W. Hribernik & E. Mrakotsky, Austrian Institute of Technology, H. Fechner & N. Prüggler, University of Applied Science Technikum Wien
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Denmark	DNK	Peter Ahm, PA Energy A/S
France	FRA	Philippe Jacquin, consultant; Yvonnick Durand ADEME
Germany	DEU	Lothar Wissing, Forschungszentrum Jülich, Projektträger Jülich
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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 and Greg Watt.

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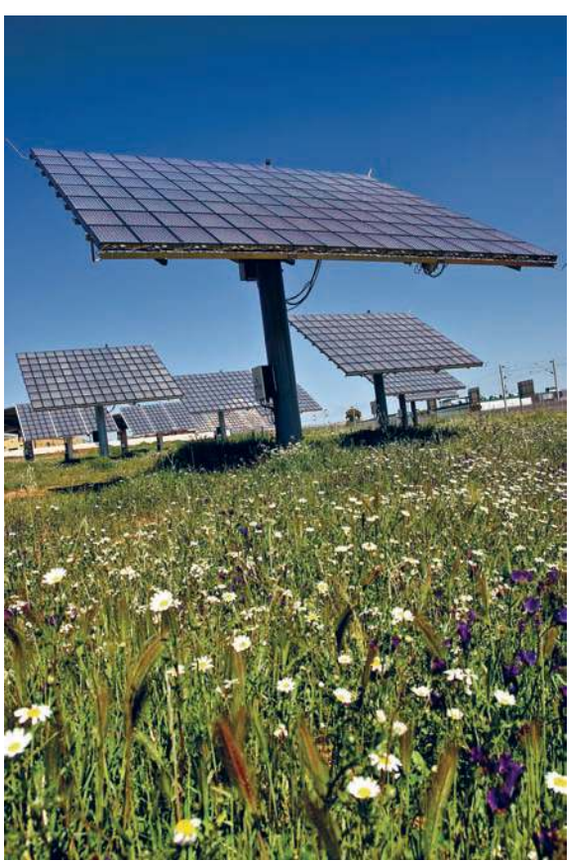
Exchange rates

Table 14 lists the reporting countries, corresponding currency codes, and the exchange rates used to convert national currencies. Exchange rates represent the 2009 annual average of daily rates (source: OECD Main Economic Indicators July 2010).

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)	1,28	Norway	krone (NOK)	6,29
Canada	dollar (CAD)	1,14	Sweden	krona (SEK)	7,65
Denmark	krone (DKK)	5,36	Switzerland	franc (CHF)	1,09
Israel	NIS	3,93	United Kingdom	pound (GBP)	0,64
Japan	yen (JPY)	93,57	United States	dollar (USD)	1
Korea	won (KRW)	1 274,95	Austria, France, Germany, Italy, the Netherlands, Portugal, Spain	euro (EUR)	0,72
Mexico	peso (MXP)	13,50			
Turkey	Turkish lira (TRY)	1,55			

(source: OECD Main Economic Indicators 2010)



Flatcon (c) CPV System of Concentrix Solar (photo: Fraunhofer-ISE, Freiburg).

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*.
Single crystal silicon (sc-Si) PV cells are manufactured using a single crystal growth method and have commercial efficiencies between 15 % and 18 %.
Multicrystalline silicon (mc-Si) cells, usually manufactured from a melting and solidification process, are becoming increasingly popular as they are less expensive to produce but are marginally less efficient, with 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 61215 Ed. 2, IEC 61646 Ed. 2.0 and IEC 61730 International Standards.

A ***PV array*** consists of a number of modules connected in series (strings), then coupled in parallel to produce the required output power.

A wide range of ***mounting structures*** has been developed especially for building integrated PV systems (BIPV), including PV facades, sloped and flat roof mountings, integrated (opaque or semi-transparent) glass-glass modules and 'PV roof tiles'. Single or two-axis ***tracking systems*** have recently become more and more attractive, particularly for PV applications in countries with a high share of direct irradiation. By using such systems, the energy yield can be typically increased by about 30 % compared with non-tracking systems.

Grid-connected PV systems

In grid-connected PV-systems, an ***inverter*** is used to convert electricity from direct current (d.c.) as produced by the PV array to alternating current (a.c.) that is then supplied to the electricity network. The typical weighted conversion efficiency – often stated as 'European' 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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