IEA INTERNATIONAL ENERGY AGENCY

TRENDS IN PHOTOVOLTAIC APPLICATIONS

Survey report of selected IEA countries between 1992 and 2011

PVPS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

Report IEA-PVPS T1-21:2012

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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 28 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 [1] 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 participating countries are Australia, Austria, Belgium, Canada, China, Denmark, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States of America. The European Commission, the European Photovoltaic Industry Association, the Solar Electric Power Association and the Solar Energy Industries Association are also members. Thailand is in the process of joining the programme.

This year's 17th edition of the IEA PVPS international survey report on Trends in Photovoltaic (PV) Applications falls together with almost 20 years of global cooperation within the IEA PVPS Programme. The history of PV market deployment over this decisive period for PV from its very first market developments to the present large scale deployment, meanwhile accounting for important shares of the newly installed capacity for electricity production, can uniquely be followed year by year in the series of IEA PVPS trends reports. 2011 has been yet another year of unprecedented further market growth, continued massive cost reduction and ongoing signs of industry and market consolidation. In total, about 28 GW of PV capacity were installed in the IEA PVPS countries during 2011 (2010: 14,2 GW), thus again doubling the installed capacity of the year before; this raised the total installed capacity in IEA PVPS countries close to 64 GW with another estimated 6 GW of capacity installed in further countries. 60 % of the total capacity was installed in Italy and Germany alone. If China, the US, Japan and France are included, then over 86 % of PV installations in 2011 occurred in six countries. Nine countries have, or are close to achieving, annual markets exceeding 1 GW. This trend marks an important development: The number of countries installing large amounts of PV capacity increases every year, thus improving the balance of countries within the global PV market distribution which should contribute to stabilizing the market over time. At the same time, production of PV cells and modules has largely surpassed the amount of PV installed, thereby creating an important overcapacity with all the consequences of cost reduction and consolidation within the industry. Even lower prices of PV modules (average 1,4 USD/W) and systems (average 3,6 USD/W, lowest 2,0 USD/W) have been reported. In sunny countries, PV generation costs can now match the price of retail electricity, another development that arrived sooner than many anticipated. At the same time, this leads to challenges in the way that electricity markets operate. These developments have created difficult situations for a number of PV companies, quite a few having to close down their operations. Overall, 2011 has thus been a very dynamic but also difficult year for the PV sector; however, the prospects of further market development remain excellent. Read all the details of the IEA PVPS market and industry analysis and get insight in the relevant developments of the sector!

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.

To obtain additional copies of this report or information on other IEA PVPS publications please visit the IEA PVPS website www.iea-pvps.org.

Introduction

Trends report scope and objective

As part of the work of the IEA PVPS programme, annual surveys of photovoltaic (PV) power applications and markets are carried out in the reporting countries. The objective of the series of annual Trends reports is to present and interpret developments in both the PV systems and components being used in the PV power systems market and the changing applications for these products within that market. These trends are analyzed in the context of the business, policy and non-technical environment in the reporting countries.

This report is not intended to serve as an introduction to PV technology. It is prepared to assist those responsible for developing the strategies of businesses and public authorities, and to aid the development of medium term plans for electricity utilities and other providers of energy services. It also provides guidance to government officials responsible for setting energy policy and preparing national energy plans.

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

This report presents the results of the 17th international survey. It provides an overview of PV power systems applications, markets and production in the reporting countries and elsewhere at the end of 2011 and analyzes trends in the implementation of PV power systems between 1992 and 2011.

Green Utility SpA-owned Si-a 4,3 MWp PV plant, Rimini Fair, by the contractor Acea Arse SpA

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. A list of the national authors is given at the end of this publication.

Definitions, symbols and abbreviations

Standard ISO symbols and abbreviations are used throughout this report. The electrical generation capacity of PV modules is given in watts (W). This represents the rated power of a PV device under standard test conditions of 1 000 W·m-2 irradiance, 25°C cell junction temperature and solar reference spectrum AM 1,5.

The term PV system includes the photovoltaic modules, inverters, storage batteries and all associated mounting and control components as appropriate. Supply chain refers to the procurement of all required inputs, conversion into finished PV products, distribution and installation of these products for final customers. The value chain looks at how increased customer value can be created across a company's business activities, which can include design, production, marketing, delivery and support functions.

Currencies are either presented as the current national currency (where it is considered that the reader will receive most benefit from this information) or as euros (EUR) and/or US dollars (USD) (where direct comparisons between countries' information is of interest). Care should be taken when comparing USD figures in this report with those in previous reports because of exchange rate movements. The exchange rates used for the conversions in this report are given at the end of this report.

1 IMPLEMENTATION OF PHOTOVOLTAIC SYSTEMS

1.1 Applications for photovoltaics

There are four primary applications for PV power systems:

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

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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.

2 MW Hydro/PV Generating System in Yushu, Qinghai Province, China

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.

PV and solar thermal combined on a Swiss house, courtesy SOLTOP AG

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.

8 MW PV on landfill, Pajam, Malaysia

1.2 *Total photovoltaic power installed*

About 28 GW of PV capacity were installed in the IEA PVPS countries during 2011 – roughly double the amount as in the previous year. This brought the cumulative installed capacity to almost 63,6 GW. By far the greatest proportion (about 60 %) was installed in Germany and Italy alone. If China, the US, France and Japan are also included, then over 86 % of PV installations in 2011 occurred in six countries with over 1 GW. In 2011, six countries, namely Italy, Germany, China, US, France and Japan achieved annual installation of 1 GW, compared to three (Germany, Italy and the Czech Republic) globally in 2010.

The annual rate of growth of cumulative installed capacity in 2011 in the IEA PVPS countries was 82 %, up from 68 % growth rate in 2010. The worldwide annual installed PV capacity during 2011 is estimated to be a little less than 30 GW.

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.

Table 1 – Reported PV power capacity in participating IEA PVPS countries as of the end of 2011

Country	Cumulative off-grid PV capacity* (MW)		Cumulative grid-connected PV capacity (MW)		Cumulative installed PV power (MW)	Cumulative installed per capita (W/Capita)	PV power installed during 2011 (MW)	Grid-connected PV power installed during 2011 (MW)
	domestic	non-domestic	distributed	centralized				
AUS	101,8	62	1 236,8	7,4	1 407,9	62,1	837	761
AUT	4,5		182,7		187,2	22,1	91,7	91
BEL					2 000	182,6	963	963
CAN	23,3	37,7	131,6	366,1	558,7	16,0	277,6	276,7
CHE	4,4		204,1	2,6	211,1	26,5	100,2	100
CHN	81,8	36,3	774	2 391,9	3 300	2,4	2 500	2 485
DEU			24 820		24 820	303,2	7 500	7 500
DNK	0,3	0,5	15,9	0	16,7	3,0	9,7	9,5
ESP					4 260	92,0	345	345
FRA	29,4		2 289	513	2 831,4	43,3	1 634,1	1 634
GBR					976	15,7	899	899
ISR	3,5	0,3	186	0	189,7	24,1	119,6	119,4
ITA		10	4 208,7	8 584,2	12 802,9	210,5	9 304,6	9 303,6
JPN	5,5	97,7	4 741,5	69,2	4 913,9	38,5	1 295,8	1 291,3
KOR	1	5	177,3	629	812,3	16,7	156,7	156,7
MEX	27,4		7,7	2	37,1	0,3	6,5	4,5
MYS	11		2,5		13,5	0,3	0,9	0,9
NLD	5,4		126		131,4	7,9	43	43
NOR					9	1,8	< 1	< 1
PRT	3,2		140,4		143,6	13,6	12,8	12,7
SWE	5,7	0,8	8,87	0,4	15,8	1,7	4,3	3,6
TUR					7	0,1	1	1
USA			2 828	1 137	3 966	12,6	1 867	1 867
Estimated totals for all IEA PVPS countries (MW)	**1 190**		**62 421**		**63 611**		**27 970**	**27 869**

Notes:
**Some off-grid capacity, installed since the 1970's, has been de-commissioned in various countries but is difficult to quantify.*
The characteristics of some national markets, particularly the relative effectiveness of grid connection procedures, can cause disparities between capacity physically installed and capacity recorded as operational.
ISO country codes are outlined in Table 13.

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

Country	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
AUS	7,3	8,9	10,7	12,7	15,7	18,7	22,5	25,3	29,2	33,6	39,1	45,6	52,3	60,6	70,3	82,5	104,5	187,6	570,9	1 407,9
AUT	0,6	0,8	1,1	1,4	1,7	2,2	2,9	3,7	4,9	6,1	10,3	16,8	21,1	24,0	25,6	27,7	32,4	52,6	95,5	187,2
BEL	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	2 000
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	16,8	20,5	25,8	32,7	94,6	281,1	558,7
CHE	4,7	5,8	6,7	7,5	8,4	9,7	11,5	13,4	15,3	17,6	19,5	21,0	23,1	27,1	29,7	36,2	47,9	73,6	110,9	211,1
CHN	~	~	~	~	~	~	~	~	19	23,5	42	52	62	70	80	100	140	300	800	3 300
DEU	3	5	6	8	11	18	23	32	76	186	296	435	1 105	2 056	2 899	4 170	6 120	9 914	17 320	24 820
DNK	~	0,1	0,1	0,1	0,2	0,4	0,5	1,1	1,5	1,5	1,6	1,9	2,3	2,7	2,9	3,1	3,3	4,6	7,1	16,7
ESP	~	~	1	1	1	1	1	2	2	4	7	12	24	49	148	705	3 463	3 523	3 915	4 260
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	380,2	1 197,3	2 831,4
GBR	0,2	0,3	0,3	0,4	0,4	0,6	0,7	1,1	1,9	2,7	4,1	5,9	8,2	10,9	14,3	18,1	22,5	26,0	69,8	976
ISR	~	~	~	~	~	~	~	~	~	~	~	~	0,9	1,0	1,3	1,8	3,0	24,5	69,9	189,7
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	3 502,3	12 802,9
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	3 618,1	4 913,9
KOR	1,5	1,6	1,7	1,8	2,1	2,5	3,0	3,5	4,0	4,7	5,4	6,0	8,5	13,5	35,9	81,2	357,6	524,2	655,6	812,3
MEX	5,4	7,1	8,8	9,2	10,0	11,0	12,0	12,9	13,9	15,0	16,2	17,1	18,2	18,7	19,7	20,8	21,8	25,0	30,6	37,1
MYS	~	~	~	~	~	~	~	~	~	~	~	~	~	~	5,5	7,0	8,8	11,1	12,6	13,5
NLD	1,3	1,6	2,0	2,4	3,3	4,0	6,5	9,2	12,8	20,5	26,3	45,7	49,2	50,7	52,2	52,8	56,8	67,5	88	131,4
NOR	3,8	4,1	4,4	4,7	4,9	5,2	5,4	5,7	6,0	6,2	6,4	6,6	6,9	7,3	7,7	8,0	8,3	8,7	9,1	9
PRT	0,2	0,2	0,3	0,3	0,4	0,5	0,6	0,9	1,1	1,3	1,7	2,1	2,7	3,0	3,4	17,9	68,0	102,2	130,8	143,6
SWE	0,8	1,0	1,3	1,6	1,8	2,1	2,4	2,6	2,8	3,0	3,3	3,6	3,9	4,2	4,8	6,2	7,9	8,8	11,4	15,8
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	6,0	7
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	1 616	2 534	3 966
Total	**103**	**127**	**151**	**182**	**220**	**282**	**356**	**473**	**697**	**990**	**1 378**	**1 866**	**2 969**	**4 389**	**5 850**	**8 312**	**14 453**	**20 758**	**35 036**	**63 611**

Notes: Totals reflect conservative 'best estimates' based on the latest information made available to the IEA PVPS Programme from the individual countries for previous years, and are updated each year as required.

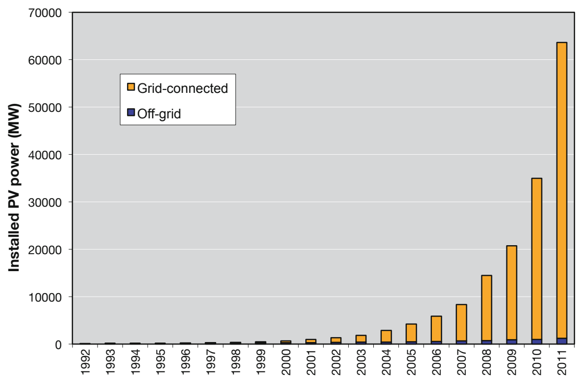

Figure 1 – Cumulative installed grid-connected and off-grid PV power in the reporting countries

Figure 1 illustrates the cumulative growth in PV capacity since 1992 within the two primary applications for PV. Particularly with the recent levels of growth seen in IEA PVPS member countries, this reported installed capacity represents a significant and increasing proportion of worldwide PV capacity.

Six countries rank in the GW annual installed PV capacity grouping. Italy's cumulative installed capacity grew at 266 % whereas Germany's growth rate was 43 %. China's cumulative installed capacity experienced an almost four-fold increase. Cumulative installed capacity increased by 56 % in the US and 36 % in Japan. France's cumulative installed PV capacity increased by 169 %.

Continued dramatic growth of the annual grid-connected PV market worldwide is shown in Table 3a. Significant growth of the annual market was evident in a number of the largest markets (Table 3b).

In 2011, the Italian annual PV market was largest amongst all the countries (the position previously held by Germany). The second largest market was Germany, exceeding any other country's annual market by a massive 5 GW, with quite a drop to China followed by the US and France, then Japan followed by Belgium. Germany still has the highest level of installed capacity in terms of total capacity (about 24,8 GW) and by far the highest installed capacity per capita (over 303 W/capita).

The off-grid market

With so much emphasis on the relatively large numbers associated with grid-connected markets, off-grid markets tend to be ignored. This is unfortunate as these applications have the scope to dramatically change the lives of some of the world's most disadvantaged peoples. The off-grid market itself is healthy with sustained, solid growth over decades, and not subject to the same sort of political

Table 3a – Annual installed photovoltaic power (MW) in all IEA PVPS countries – historical perspective (1995–2011)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Off-grid	20	26	29	29	28	33	42	35	56	40	35	50	128	78	142	97	101
Grid-connected	10	12	33	45	88	174	246	336	425	1 018	1 332	1 589	2 337	6 068	6 123	14 098	27 869

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

Table 3b – Annual photovoltaic power (MW) installed in the top-ten cumulative capacity countries – historical perspective (1995–2011)

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
AUS	2,0	3,0	3,0	3,8	2,8	3,9	4,4	5,5	6,5	6,7	8,3	9,7	12,2	22,0	79,1	383,3	837
BEL	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	421	963
CHN	~	~	~	~	~	3	4,5	18,5	10	10	8	10	20	40	160	500	2 500
DEU	2	3	7	5	9	44	110	110	139	670	951	843	1 271	1 950	3 794	7 406	7 500
ESP	~	~	~	~	~	~	2	3	5	11	25	99	557	2 758	60	392	345
FRA	0,5	1,5	1,7	1,5	1,5	2,2	2,6	3,3	3,9	5,2	7,0	10,9	31,3	104,5	155,5	719	1 634,1
GBR	~	~	~	~	~	~	~	~	~	~	~	~	~	4,4	7,1	40,1	899
ITA	1,7	0,2	0,7	1,0	0,8	0,5	1,0	2,0	4,0	4,7	6,8	12,5	70,2	338,1	723,0	2 320,9	9 304,6
JPN	12,1	16,3	31,7	42,1	75,2	121,6	122,6	184,0	222,8	272,4	289,9	286,6	210,4	225,3	483,0	991,0	1 295,8
USA	9,0	9,7	11,7	11,9	17,2	21,5	29,0	44,4	63,0	100,8	103,0	145,0	206,5	338,0	447,5	918,0	1 867

whims and flights of fancy as grid-connected PV. This market is also largely unsupported by public funding. Of the total capacity installed in the IEA PVPS countries during 2011, less than 0,4 % were installed in off-grid projects and these now make up about 2 % of the cumulative installed PV capacity of the IEA PVPS countries. Figure 2 shows the dominance now achieved by grid-connected applications in an increasing number of countries. It is interesting to note that it was only a little over one decade ago that the installed capacities of off-grid and grid-connected applications were divided almost equally. Figure 3 provides a snapshot of the off-grid/grid-connected installed capacities in some selected markets.

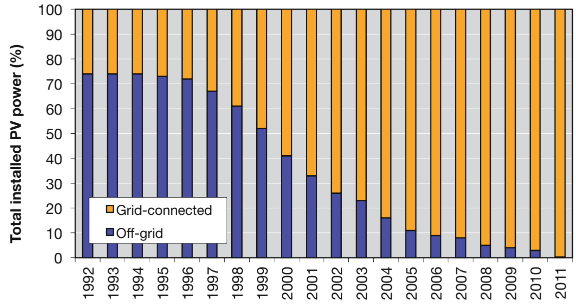

Figure 2 – Percentages of grid-connected and off-grid PV power in the reporting countries

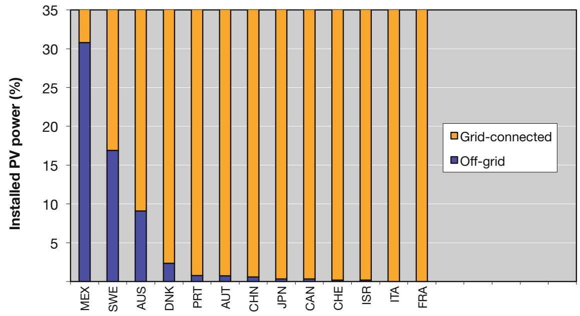

Figure 3 – Installed PV power in selected reporting countries by application (%) in 2011

1.3 PV implementation highlights from selected countries

The information presented in this section, outlining activity occurring during calendar year 2011, 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. Some countries have not provided national survey reports.

Australia (AUS)

A total of 837 MW of PV were installed in Australia in 2011, more than twice the capacity added in 2010. Of this 91 % was grid-connected, taking the cumulative grid-connected portion to 88 %, up from 84 % last year. Total installed capacity in Australia is now 1,4 GW. PV power has now reached grid parity in many areas and government support programmes are winding down. During 2011, PV capacity reached about 3 % of total national electricity generation capacity, with about 36 % of new electricity generation capacity installed during the year being PV.

Australian Government support programmes impacted significantly on the PV market in 2011. The 45 000 GWh Renewable Energy Target (RET) consists of two parts – the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES). Liable entities need to meet obligations under both the SRES and LRET by acquiring and surrendering renewable energy certificates created from both large and small-scale renewable energy technologies. The SRES covers small generation units (small-scale PV, small wind turbines and micro hydroelectric systems) and solar water heaters, creating small-scale technology certificates (STCs). Deeming arrangements mean that PV systems up to 100 kW can claim 15 years' worth of STCs up-front. Solar Credits work by multiplying the number of renewable energy certificates that these systems would generally be eligible to create under the standard deeming arrangements. The multiplier can be changed by government to influence demand for small-scale PV systems.

The Solar Homes and Communities Plan provided up-front rebates for small-scale PV systems and, although the programme ended on 9 June 2009, a very large number of pre-approval applications were received in the closing days and installations under the programme occurred through to 2011. A total of 155,62 MW of PV have been installed under this programme, with only 200 kW installed during 2011. The vast majority of this was for grid-connected installations, with only 4,946 MW off-grid installations (none in 2011).

State based feed-in tariffs saw widespread reductions and closures during 2011. The changes that occurred were:

- The Victorian feed-in tariff (called the Premium Feed-in Tariff) closed from 30 September 2011 as it had reached its cap. Net metering (called the Standard Feed-in Tariff) continued to be available for systems up to 100 kW.

- The South Australian Feed-in Tariff was reduced from 0,44 AUD/kWh to 0,16 AUD/kWh from 1 October 2011 and eligible systems receive the payment only until 30 September 2013.
- In the ACT, systems up to 30 kW were eligible for an 0,457 AUD/kWh feed-in tariff until 31 May 2011. Systems from 30 kW up to 200 kW were eligible for a feed-in tariff of 0,3427 AUD/kWh from April 2011 (capped at 15 MW). From 12 July 2011, both size categories became eligible for the 0,3427 AUD/kWh feed-in tariff. The 15 MW cap was reached by 13 July 2011 and the scheme was closed for all systems.
- The New South Wales 0,20 AUD/kWh gross feed-in tariff was closed to new applications from midnight 28 April 2011.
- The Western Australian 0,40 AUD/kWh net feed-in tariff was reduced to 0,20 AUD/kWh from 30 June 2011, then closed to new applications from 1 August 2011.

All seven Solar Cities are entering the final reporting and analysis phase of their projects. One key finding has been the benefit of community engagement campaigns that promote behavioural change.

The Australian Government's National Solar Schools Programme (NSSP) assists schools to take practical action in the fight against climate change. It offers eligible primary and secondary schools the opportunity to compete for grants of up to 50 000 AUD to install solar and other renewable power systems, solar hot water systems, rainwater tanks and a range of energy efficiency measures. Around 90 % of approved schools have chosen to install a PV system with their NSSP funding. In the 2011–12 funding round, 784 schools have shared in over 25 million AUD. Almost 2 000 applications were received in the 2011–12 funding round. By the end of the programme (May 2012) it is expected that approximately 60 % of all eligible primary and secondary schools in Australia will have received an NSSP grant.

In May 2009 the Australian Government announced a call for 1 GW of solar generation via four solar power stations (solar thermal and PV). The Solar Flagships Programme is split over two funding rounds with the first round to target 400 MW of electricity generation. From the 52 proposals for funding in Round 1 of the programme, two were selected in June 2011: the 150 MW Moree Solar Farm (PV) and the 250 MW Solar Dawn (solar thermal) projects. Neither project was able to achieve financial close by end 2011 and this phase of the programme was extended.

Bushlight is an Australian Government-funded national, non-profit project that installs renewable energy systems in remote Indigenous communities (known as homelands) throughout central and northern Australia. Each system installation is preceded by, and carried out in conjunction with, a comprehensive programme of community engagement, education and training. In 2011, Bushlight installed five new renewable energy systems, with a combined total output of 91,2 kW of PV. Bushlight upgraded four systems with an additional 9,51 kW. Bushlight's maintenance programme provided scheduled servicing and ongoing support to 265 renewable energy systems located in 220 communities. Under the Renewable Remote Power Generation Programme (RRPGP) – closed in 2009 – some large-scale projects are completing construction and expect to be finished by the end of 2012.

Austria (AUT)

In 2011 the Austrian domestic PV system market showed a significant increase compared to 2010. In 2011, off-grid and grid-connected PV systems with a total capacity of 91,67 MW were installed, representing a 112 % annual growth rate. The cumulative installed PV capacity in Austria reached 187,17 MW by the end of 2011. Grid-connected applications increasingly dominate the market for PV, accounting for about 182,67 MW of the total installed capacity at the end of 2011. On a ten-year basis, average market growth of 53,9 % per year for all PV installations can be observed.

The revised Green Electricity Act (GEA) forms the framework for national PV implementation in Austria. The nationwide feed-in tariff system for electricity introduced under the GEA is financed by all consumers of electricity via supplements on the electricity price and an obligatory purchase price for Green Electricity that is paid by electricity dealers. Feed-in tariffs are exclusively available for privately-owned systems larger than 5 kW. The amount paid under the 2011 PV feed-in tariff increased to approximately 19,3 MEUR, an increase of 39,3 % over the previous year. Average feed-in tariffs were reduced by 7,1 % compared to 2010. The PV electricity produced climbed from about 26,3 GWh to 39,4 GWh.

Solar skate park on Magnetic Island, Australia.
Photo: Townsville Solar City

Besides the federal feed-in tariff scheme, rebates for new PV installations are provided on the national (National Fund for Climate and Energy) and provincial levels. In 2011 30,4 MEUR were granted under this funding scheme, leading to an installed capacity of over 27 MW (up from 11 MW in 2010).

Some Austrian provinces (Burgenland, Lower Austria, Upper Austria, Salzburg, Styria, Vienna) are running separate regional rebate programmes, aimed at overcoming the limitations of federal incentives. In most cases the support is subject to limited budgets and is linked to further requirements. Generally, the regional support is only granted where the installation is not supported by the federal feed-in tariff scheme. The remaining provinces offer a support scheme in cooperation with the federal Fund for Climate and Energy. In 2011 the regional funding initiatives helped to install a total PV capacity of 38,9 MW.

Belgium (BEL)

About 963 MW of PV were installed during 2011, mostly in the region of Flanders, compared with about 421 MW in 2010. Cumulative capacity reached 2 GW at the end of 2011. 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. PV incentives have been reduced for larger PV systems, and roof-top size systems are favored. The support schemes for PV are expected to be drastically reduced in 2012.

Canada (CAN)

Canada's cumulative installed PV capacity almost doubled to 559 MW in 2011 compared to 2010 and includes installations on buildings amounting to 132 MW and centralized applications amounting to 366 MW. Total PV sales in Canada in 2011 were 278 MW, mostly within the grid-connected market segment. This is a significant growth sector that is spurred by the Province of Ontario's feed-in tariff launched in 2006 and expanded in 2009. The grid-connected applications included 104 MW for residential and building-integrated applications and 173 MW for large ground-mounted utility-scale systems.

The Province of Ontario leads the country in PV investment. Ontario's Feed-in Tariff programme is North America's first comprehensive guaranteed pricing structure for electricity production from renewable sources. The programme is divided into two streams: the first targets the renewable energy projects generating more that 10 kW of electricity (referred to as the 'FIT Programme'), and the second targets small renewable projects generating 10 kW of electricity or less, such as home or small business installations (referred to as the 'microFIT Programme'). Prices paid for renewable energy generation under the FIT and microFIT programmes vary by energy source and take into account the capital investment required to implement the project. Under the programme, PV systems can enter into a 20-year contract to receive a fixed price of up to 0,802 CAD/kWh for the generated electricity. In October 2011 the Province of Ontario began its scheduled two-year Feed-in Tariff review.

In provinces such as Alberta, consumer uptake of PV is being explored by local electricity utilities. Calgary's ENMAX electricity utility offers installed PV systems with a zero upfront investment cost and a 15-year lease-to-own programme, including a parts and labour warranty and ongoing service agreements. With net metering, customers can reduce their monthly electricity bills according to the amount of PV electricity they generate. Net metering regulations are in place in most provinces and territories in Canada.

A non-profit co-operative, SolarShare, allows individual Ontario investors to buy 1 000 CAD bonds with a guaranteed 5 % return over five years. These bonds are considered attractive and especially low-risk because they are applied to already existing projects with 20-year contracts under the Ontario Power Authority Feed-in Tariff programme. AGRIS Solar, working with farmers in Ontario, and the Community Power Fund are examples of other co-operative organizations enabling citizen investment in PV projects with predictable returns made possible through the FIT programme. In addition, non-profit organizations such as the Ontario Sustainable Energy Association and the Community Energy Partnership Programme are facilitating community co-operative investments in PV with toolkits, workshops and user-group forums, and grant money for the initial investment.

China (CHN)

About 2 500 MW of PV were installed in China in 2011, a fivefold increase on 2010 levels. Total installed capacity in China reached close to 3 300 MW, up from 100 MW four years ago. The Chinese Government is now providing strong support via incentive policies and financial measures to expand the domestic Chinese PV market, in an attempt to better balance domestic industrial production of PV and local PV market demand.

Of the PV capacity installed during 2011, some 2 000 MW were large-scale grid-connected power stations, 480 MW were building-integrated or building-attached systems, and about 15 MW were installed for rural electrification and off-grid industrial applications. Since 2008 large-scale plants have been developed in China and are now clearly the dominant application. In more recent years building-related PV has been receiving strong support from the government and is playing an increasingly important role in the Chinese PV market.

The major market support demonstration programmes in China are the Solar PV Building Project and the Golden Sun Programme, both of which commenced in 2009. Both programmes offer capital subsidies to support a variety of PV applications. The government also operates a concession programme for development of utility-scale PV power stations, with kWh payments allocated as a result of a bidding process. In China this is referred to as the nationwide feed-in tariff (announced in July 2011), with 1,15 CNY/kWh allocated for projects finished before end 2011 and 1,0 CNY/kWh allocated for those completed thereafter.

In November 2011, the surcharge for renewable energy collected via electricity bills was doubled to 0,008 CNY/kWh (about 1,5 % of a typical household retail electricity price). This will allow 20 to 24 BCNY (or about 3,5 BUSD) to be collected each year to support renewable power generation.

Also late in 2011 the Chinese PV installed capacity goal for 2015 was updated from 10 GW to 15 GW, meaning an annual market of some 3 GW to 4 GW of PV each year until 2015. Utility-scale PV power stations and distributed generation will each have their own distinct market frameworks. It is anticipated that the annual market may reach 10 GW per year in the period up to 2020 and will exceed 20 GW per year thereafter.

Denmark (DNK)

By the end of 2011 Denmark (including Greenland) had about 17 MW of PV installed in total, an increase of more than 9 MW compared to 2010. Grid-connected distributed systems make up the majority (90 %) of PV systems in Denmark. In Greenland stand-alone PV plays a major role as the power source for remote signaling and for the telecommunication network.

Denmark has no general incentive for reducing the investment cost of PV systems but has a net-metering scheme set by law for private households and institutions. Due to higher taxes on electricity and the climbing retail electricity prices, the net-metering scheme is increasingly driving the PV market as illustrated by an annual market increase from 2010 to 2011 of 140 %. The main PV application during 2011 was PV rooftops on residential houses – a market driven by the net-metering scheme. With electricity retail prices around 2,10 DKK a typical payback period of around ten years can be achieved. Very healthy growth continues into 2012 and many new commercial actors are becoming active.

The EU directive on energy consumption in buildings, minted into a revised national building code in 2005 and moved into force early 2006, specifically mentions PV and allocates PV electricity a factor of 2,5 in the calculation of the energy footprint of a building. From around 2009 it was possible to detect tangible impact on PV deployment, as developers, builders and architects included BIPV in projects specifically due to the building codes. This trend markedly strengthened during 2011. Ongoing political discussions both on the EU level and nationally point to a tightening of the building codes, which may further promote BIPV in Denmark. The future energy requirements in the building codes are now known up to 2020 and many new buildings are in compliance with these future codes.

France (FRA)

The grid-connected PV power installed in France during 2011 amounted to 1 634 MW, up from 817 MW in 2010, representing 57 % of newly installed electricity generation capacity. The 100 % annual market increase derives mainly from medium-scale systems (36 kW to 250 kW) and large-scale systems (> 250 kW) contributing to 36 % and 46 % respectively of the annual installed power. 432 MW of ground-mounted centralized systems and 1 232 MW of distributed systems (mainly building applications) were connected to the electricity grid during 2011. In 2011, power installations of less than or equal to 3 kW (residential rooftops) represent 12 % of the installed power but 87 % of the number of systems installed that year.

The majority of French PV installations are located in regions where there is the most sunshine. The most active regions include Provence – Alpes – Côte d'Azur (13 % of the total cumulative power), Midi-Pyrénées (10 %), Aquitaine (10 %), Languedoc-Roussillon (9 %), Pays de la Loire (7 %) and Rhône-Alpes (7 %). Reunion Island accounts for 50 % of the installed power in the overseas departments and 5 % of the total national photovoltaic power.

France's PV development objective is to have 5 400 MW of PV connected by 2020. To reach this objective the Government decided to control the development and financial impact on the CSPE tax (public electricity service contribution financed by electricity consumers through their bills) by setting up a system of feed-in tariffs for projects of capacity up to 100 kW. Revised in March 2011, feed-in tariffs are now indexed every quarter based on the number of projects submitted during the preceding quarter. The tariffs also depend on the degree of integration of the PV modules, the installation power and the type of building. Above 100 kW the support scheme involves a tendering procedure. The annual target is 500 MW for installations wanting to benefit from the support schemes: 100 MW for building-integrated residential installations up to 36 kW, 100 MW for installations between 36 kW and 100 kW, 120 MW for installations between 100 kW and 250 kW, and 180 MW for installations of more than 250 kW. The target can be reconsidered and increased to 800 MW after revision of the multi-year national investment programme for electricity production.

The reduction in feed-in tariffs every three months depends on the number of grid-connection requests made during the previous quarter. For building-integrated installations up to 3 kW, the tariff dropped from 0,58 EUR/kWh at the start of 2011 to 0,388 EUR/kWh at the start of 2012. For ground-mounted plants, the tariff dropped from about 0,3 EUR/kWh at the start of 2011 to 0,11 EUR/kWh one year later. PV electricity purchase contracts are managed financially by the EDF Compulsory Purchase Agency and other local electricity distribution subsidiaries.

The first phase of the 120 MW Invitation to Tender, concerning the construction of PV installations of 100 kW to 250 kW on buildings, was launched on 17 July 2011. The French Energy Regulation Commission (CRE)) received applications for 345 projects (68 MW). The CRE launched a second type of invitation to tender on 15 September 2011, concerning PV power applications of greater than 250 kW.

Germany (DEU)

Market support measures continued to sustain the installation of grid-connected PV systems in Germany during 2011, resulting in 7,5 GW of new grid-connected PV capacity for the year, much the same amount as in 2010. The German cumulative capacity has now reached 24,82 GW of PV connected to the electricity grid.

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

Under the EEG a uniform annual reduction of the PV feed-in tariff was envisaged. To better manage the dynamic PV market that emerged, a mechanism was introduced to adapt the feed-in tariffs to the magnitude of the growth in the market. Under this mechanism, the feed-in tariff reductions are increased or decreased if the market deviates from a pre-defined corridor. For 2010 to 2012, the corridor for the annual market was set between 2 500 MW and 3 500 MW. With around 7 500 MW of PV installed in 2011 the corridor was clearly eclipsed and consequently additional adaptations for the tariffs are under discussion.

With German PV electricity now around parity with retail electricity prices, amendments to the EEG aim to promote consumers' own consumption of PV electricity to a greater degree, with private households not feeding solar electricity into the grid but consuming it themselves to gain up to 0,08 EUR/kWh. Businesses will also benefit from the amendment as the provision will apply to PV installations with a capacity of up to 500 kW (100 times the capacity of a typical German single-family home rooftop PV system). It is anticipated that this provision concerning own-consumption will trigger further important technological progress, for example in the field of storage technology. Furthermore, consumption of grid electricity will be reduced, easing the demand on the grid (and possibly introducing new financial issues for the electricity industry).

In contrast to previous EEG stipulations, open space installations will continue to be promoted beyond 1 January 2015. The areas allowed for PV installations qualifying for the feed-in tariffs under the EEG can also include land converted from residential building or transport use in addition to land converted from agricultural or military use. Open space installations can now also be developed in a 100 m wide margin alongside motorways and railway tracks. The arable land category no longer applies from 1 July 2010. Transitional arrangements for open space installations already having reached an advanced planning stage are in existence.

Germany has a wide range of policy and promotional initiatives. In addition to the EEG, PV in Germany receives support from local fiscal authorities (providing tax credits for PV investments) and the state owned bank KfW-Bankengruppe (providing loans for individuals and local authorities for measures to reduce energy consumption plus the application of renewable energies in buildings). Some federal states also provide grants for PV plants.

Israel (ISR)

During 2011 almost 120 MW of PV were installed in Israel, more than two and a half times the previous year's annual market, bringing the cumulative installed capacity to over 189,7 MW. Nearly all the PV systems installed were grid-connected. The majority of projects were rooftop systems, with farms, industry and municipalities (for example municipal buildings and schools) dominating installations. Small and medium-sized grid-connected systems now dominate the Israeli cumulative installed PV capacity comprising about 98 % of the total. The major application of the few stand-alone systems continues to be providing electricity for members of the Bedouin population who are not connected to the electricity grid.

Since July 2008 when the feed-in tariff was enacted by the government there has been a dramatic increase in the installation of PV systems throughout Israel. 2011 was the third full year of the feed-in tariff scheme. After an initial dramatic increase in the number of installation companies, inconsistent government policy concerning extending and raising quotas for installed PV is contributing to uncertainty within the industry, with many of the smaller companies not surviving. One feature of 2011 was the surprise ending of the second commercial quota mid-year and a consequent lack of progress on medium sized projects due to regulatory issues.

Israel's first large-scale PV plant was commissioned in 2011. It was developed by the Arava Power

10 MW Komekurayama Solar Power Plant, (Kofu City, Yamanashi Prefecture), Owner: TEPCO (Tokyo Electric Power Company)

Company and installed at Kibbutz Ketura in the Arava Valley. The 4,95 MW plant cost 100 million NIS, created 60 jobs during construction and five ongoing positions and will produce 9 GWh/year.

Italy (ITA)

PV power installed in Italy during 2011 reached 9304,6 MW, over 60 % of all new electricity generation capacity. Cumulative installed and operating PV power reached 12803 MW. Italian PV electricity production now provides 10 TWh of electricity or about 3 % of the national electricity consumption. The grid-connected distributed and grid-connected centralized PV power systems markets continue to grow rapidly and now account for almost 33 % and 67 % respectively of the total installed PV capacity in Italy. Almost all off-grid domestic systems have been decommissioned; off-grid non-domestic applications continue to increase slowly.

The national market stimulation initiative in operation during the year was the Conto Energia Programme (second, third and fourth phase). The programme represents a long-standing sustained approach to stimulation of the market. The first phase, Primo Conto Energia, defined through two governmental decrees issued in 2005 and in 2006, was completed toward the end of 2009 with 5733 PV installations (corresponding to about 165 MW). The second phase, Nuovo Conto Energia, was defined through a governmental decree issued in February 2007. This phase saw the issue of the Salva Alcoa decree that extended the validity of the relevant feed-in tariffs until June 2011 and resulted in about 3650 MW installed capacity. The third phase, extending from January 2011 until June 2011) saw 1550 MW installed, while under the fourth phase about 76150 plants were installed during 2011, corresponding to some 4100 MW. Around 3 BEUR were provided for market incentive payments throughout 2011.

Two main barriers have emerged that could adversely affect the booming PV market in Italy: Firstly, the adequacy of the electricity grid in some regions of southern Italy, where the installed power of wind turbines and PV is almost the same order of magnitude as the peak load and secondly, the annual cost of the incentive tariffs is rapidly approaching the budget limits fixed by the Conto Energia Programme.

Japan (JPN)

During 2011 a total of 1295,8 MW of PV were installed in Japan, a 31 % increase beyond what was installed the previous year. Most of these installations (over 1245 MW) continued to be mainly residential, grid-connected distributed PV systems, with a further 45,9 MW comprising grid-connected centralized plants mainly installed by the electricity utilities. The PV market was led by a subsidy programme for residential PV systems and a programme to purchase surplus PV power at a preferential price from systems of less than 500 kW capacity. Cumulative installed capacity of PV systems in Japan in 2011 reached 4,9 GW or 2,1 % of total national electricity generation capacity.

The Japanese PV market is dominated by grid-connected distributed PV systems, mainly for private housing, collective housing or apartment buildings, public facilities, industrial and commercial facilities.

Residential PV systems accounted for 85,4 % of the grid-connected market in Japan in 2011. PV systems for public facilities, supported by the national and local governments, accounted for 2,1 % of the grid-connected market, while PV systems for industrial and commercial use accounted for 8,6 %. Grid-connected centralized PV systems accounted for 3,6 % of the grid-connected market in Japan. The off-grid domestic PV system market is small in size, and mainly for residences in remote areas. The off-grid non-residential PV system market operates without needing any subsidies.

In the aftermath of the Great East Japan Earthquake and the failures at the Fukushima power plant, the Energy and Environment Council of the national government began a review of Japan's energy strategy. The review focuses on reduction of dependence on nuclear power generation and expansion of both energy conservation and the use of renewable energy. Furthermore, in August 2011, the government enacted the Renewable Energy Law, under preparation since 2009, that will see Japan's Feed-in Tariff programme come into force in July 2012. The Ministry of Economy, Trade and Industry (METI) resumed the Subsidy for Installation of Residential Photovoltaic Systems in 2009 and this was continued through 2011. In addition, with the extension of the scheme to oblige electric utilities to purchase surplus electricity generated by PV systems (below 10 kW) at a preferential price, the market demand for residential PV systems has been steadily increasing. The field test and dissemination programmes underway during 2011 were the Subsidy for measures to support introduction of residential PV systems, the Programme to purchase surplus PV power, the Project for Promoting the Local Introduction of New Energy, the Project for Supporting New Energy Operators and the Project for development of stable power supply facility for emergency cases. In addition support for the dissemination and introduction of model projects for PV systems was provided by the Ministry of the Environment (MoE) as part of projects to reduce CO_2 emissions.

As part of the nationwide response to power shortages and disaster prevention after the nuclear power plant accident, local authorities and industries showed an increased willingness to install PV systems. This market segment grew to 140 MW of PV installed during 2011 in public, industrial, commercial and power sector business facilities. 875 local governments and municipalities implemented their own subsidy programmes to promote the deployment of residential PV systems. Recipients can take advantage of these subsidies in addition to the national subsidies provided by METI.

Electricity utilities constructed MW-scale PV power plants ahead of schedule and many were completed across the nation in 2011. Hokkaido Electric Power, Tohoku Electric Power, Tokyo Electric Power, Chubu Electric Power, Kansai Electric Power, Hokuriku Electric Power, Shikoku Electric Power, Kyushu Electric Power and Okinawa Electric Power have all commenced operation of large-scale PV power plants. Some utilities started on-site PV power generation businesses through their subsidiaries by installing PV systems on the rooftops of properties owned by their customers.

In the housing industry, during 2011 an increasing number of manufacturers – from major prefabricated housing manufacturers to local house builders – installed PV systems as standard items in newly-built houses for sale. The development of smart houses has been accelerated. These houses are equipped with storage batteries and home energy management systems, and may also be energy self-sufficient. The amount of installations of PV systems in condominiums increased.

Korea (KOR)

The cumulative installed power of PV system in Korea increased to 812 MW by the end of 2011. Annual installed power in 2011 reached 156 MW, which is about 20 % more than the installation capacity of 131 MW in 2010. The total capacity of 812 MW corresponds to about 1 % of total electricity generation capacity of about 83,3 GW, and the installed PV power of 156,7 MW in 2011 accounts for 5,56 % of total power generation capacity newly installed in 2011.

The share of grid-connected centralized systems is 77 % of the total cumulative installed power, and the grid-connected distributed systems account for 22 % of the total cumulative installed power. Grid-connected systems are mainly installed under the feed-in tariff programme and the One Million Green Homes programme. The share of off-grid non-domestic and domestic systems has continued to decrease to about 0,7 % of total cumulative installed power.

Sun Shine Clean Village, Daejeon, Korea

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

The One Million Green Homes Programme aims for the construction of one million green homes utilizing PV as well as solar thermal, fuel cells, wind, bio-energy and geothermal by 2020. Single-family houses and multi-family houses including apartments can benefit from this programme. The government provides 60 % of the initial PV system cost for single-family and private multi-family houses, and 100 % of the cost for public multi-family rental houses. By the end of 2011, a total of about 85,2 MW of PV capacity had been installed, involving around 95 900 households. During 2011, 19,1 MW of PV were installed, benefitting 31 000 households.

The feed-in tariff rate has been reduced considerably since 2008, and the cap was increased from 100 MW to 500 MW. Beneficiaries can choose the payment period to be either 15 years or 20 years. Up to 2011, a total of 500 MW was installed under this scheme. In 2011, 79 MW were installed. FiTs in 2010 and 2011 were reduced by 10 % to 15 % compared with the previous year. For BIPV a 10 % bonus is provided; however a BIPV system larger than 1 MW is counted as a ground-mounted system. It is planned that a Renewable Portfolio Standard will replace the feed-in tariff scheme from 2012, at which time the annual market is expected to again be larger than 200 MW.

In addition to the above, the General Deployment Subsidy Programme provides 40 % of the installation cost of PV systems with a capacity below 50 kW, and 80 % of the initial cost for special purpose demonstration and pre-planned systems, the so-called Test-period deployment subsidy programme. In 2011, a total capacity of 1,4 MW were installed in schools, public facilities, welfare facilities and universities. The Regional Deployment Subsidy Programme provides government support of 50 % of the installation cost of PV systems owned and operated by local authorities. In 2011, approximately 10,9 MW were installed under this programme. The RPS Demonstration Programme is planned to run for three years from 2009 until 2011, before the commencement of the RPS in 2012. The total capacity to be installed is fixed at 101,3 MW. Six electricity companies have constructed their own PV plants or purchase PV electricity from private operators under this programme with 31,7 MW of PV approved in 2011. Under the Public Building Obligation Programme, new public buildings larger than 3000 square meters must spend 5 % of their total construction budget installing renewable energy facilities. In 2011, approximately 14,6 MW of PV were installed under this programme.

Malaysia (MYS)

By the end of 2011 Malaysia's cumulative installed PV capacity reached about 13,5 MW, of which 2,5 MW were grid-connected. More than 60 % of the grid-connected PV systems are household installations with the remainder being associated with commercial buildings and schools. During 2011 there was close to 1 MW of grid-connected PV systems installed and a negligible amount of off-grid systems. Although the capital subsidy from the Malaysia Building Integrated Photovoltaic (MBIPV) Project ended in 2010, the increase in the installed grid-connected PV systems was largely due to the realization of the remaining financially supported projects.

2011 was a significant year for Malaysian PV policy development, with the Government passing the Renewable Energy (RE) Act 2011 and the Sustainable Energy Development Authority (SEDA) Act 2011, and the associated implementation of a feed-in tariff scheme. The opening quota for PV was 150 MW over three years (50 MW for each of years 2012, 2013 and 2014), with 90 % allocated for commercial sector developments and 10 % for homeowners. Households are permitted to install up to 12 kW PV per application, whereas the commercial developments are allowed up to 5 MW per application. The country's major national electricity utility, Tenaga Nasional Berhad (TNB) is one of the key stakeholders in the feed-in tariff implementation and collects a surcharge of 1 % on top of the electricity bill of consumers using more than 300 kWh of electricity per month. This is deposited into the RE Fund which is managed by SEDA Malaysia and will be used to pay the feed-in tariff. A feature of the Malaysian FiT scheme is the e-FiT Online System that serves an online feed-in tariff processing system. This system allows the public to submit their applications via the web; within three hours of the launch the quota for the commercial sector projects was filled.

Mexico (MEX)

During 2011 6,5 MW of PV (70 % being grid-connected systems) were installed in Mexico, somewhat less than anticipated, bringing the cumulative installed capacity to just over 37 MW.

The Netherlands (NLD)

During 2011 about 43 MW of PV were installed in the Netherlands, bringing the cumulative installed capacity to over 131 MW. This represents a doubling of the annual market compared to the previous year for the second year running. The market in 2011 increased significantly irrespective of the absence of subsidies for small systems (less than 15 kW) during the year. The market for small to medium

BIPV System at Bosch plant, Penang, Malaysia

sized PV installations has taken off, with the declining investment costs of PV leading to near grid parity in numerous cases and a consequent upsurge in public interest.

From 2008 market growth accelerated compared to previous years as a direct consequence of the start of the new subsidy tariff scheme (SDE) and the limited net metering obligation for energy companies. Over three years an average of 25 MW PV per year was allocated under SDE subsidy conditions. By the end of 2010, 18 MW of a total 69 MW were realized (with the deployment period of the first subsidy rounds remaining open). During 2011 50 MW of PV subsidies were granted under SDE+ (a total of 111 MW granted within SDE and SDE+ by the end of 2011) and some 20 MW PV were installed. A further 23 MW of PV were installed without subsidy as a result of falling prices and interesting local initiatives. 10 MW of PV were contributed by the 'Wij Willen Zon' (We Want Sun) initiative outside the SDE scheme.

Apart from the national feed-in tariff scheme, several provinces and local authorities organized regional support schemes for PV. Most regional activity originated from the provinces of Overijssel and Noord-Brabant. There has been a growth in initiatives to promote the purchase of PV modules. These include large-scale, combined purchasing actions to decrease the price of the modules and their installation, substantial discounts on PV module offerings by electricity utility companies, and schemes that provide free PV, with ownership of the system remaining with the electricity utility.

Since 2004 net metering of electricity has been legally available in the Netherlands. In February 2011 the law was amended to allow for a 5 000 kWh limit on net metering and the penalty for exceeding the limit was removed. The electricity utilities are obliged by law to deduct the PV electricity from the purchased electricity before billing thereby paying the full retail price, including energy tax and VAT, for solar electricity. While many electricity utilities objected to this in principle some are offering PV to their customers and some offer unlimited net metering.

Norway (NOR)

Less than one MW of PV was installed in Norway during 2011, mostly in off-grid systems, with the annual market remaining at much the same level as the previous six years and the cumulative installed PV capacity sitting at around 9 MW.

Portugal (PRT)

Portugal's annual PV market again fell slightly compared to the previous year. 12,75 MW of PV (99 % being grid-connected systems) were realized and the cumulative installed capacity rose to almost 144 MW. Grid-connected centralized systems account for about three quarters of the cumulative installed capacity in Portugal, and grid-connected distributed systems make up about one quarter.

Spain (ESP)

During 2011 annual installed PV power in Spain rebounded somewhat to reach 345 MW. Cumulative installed capacity reached 4 260 MW. Currently 99 % of PV installations in Spain are grid-connected systems, with the total number of PV systems exceeding 57 600.

During 2011 new procedures and technical regulations were published: connection to the electricity network of low-power electrical energy production facilities (Royal Decree 1699/2011) and self-consumption associated with PV installations (Royal Decree 1544/2011). The former impacts PV facilities of less than 100 kW installed capacity that are directly connected to a low voltage distribution network and the latter stipulates the technical and economic conditions relating to the consumption of electricity produced by the consumer.

According to the national action plan for renewable energies, by 2020 the share of renewables in final energy consumption should increase to 20 %, with 3,6 % of the Spanish electricity energy demand in 2020 to be met by PV electricity.

Sweden (SWE)

Annual installed PV power in Sweden in 2011 reached 4,3 MW – up from 2,7 MW installed the previous year. Grid-connected installations accounted for close to 84 % of the market. The off-grid market grew slightly due to lower module prices and a growing interest in PV. The cumulative installed power of PV systems in Sweden increased to 15,75 MW by the end of 2011. There was an increase in electricity utility interest in surplus electricity produced by small-scale renewable systems such as PV. From one company buying surplus electricity in 2010, 2011 saw a number of electricity utilities launching compensation schemes and some network businesses introduced net metering (although there is uncertainty how these relate to current tax laws).

A direct capital subsidy for installation of PV systems has been in operation in Sweden since 2009. This subsidy was planned to end at the close of 2011 but, in October 2011, was extended for one year and a budget for 2012 was allocated. The subsidy applies to any type of grid-connected PV system completed by 31 December 2012 and is targeted at companies, public organizations and private individuals. In 2011 the subsidy covered 60 % (55 % for big companies) of the installation cost of PV systems, including both material and labor costs. In the new ordinance for 2012 this has been lowered to 45 % to follow the decreasing system prices in Sweden. The subsidy in 2011 had an upper limit of 2 MSEK per PV system and a maximum of 75 000 SEK plus VAT per installed kW. These numbers have also been lowered in the 2012 ordinance. In 2011 58,5 MSEK were granted to different system applications, which makes the total amount granted from the 2009 start of the programme 212 MSEK. The budget for 2012 is 60 MSEK.

In 2003, a tradable green electricity certificate system was introduced in Sweden to increase the use of renewable electricity, with the objective of increasing renewable electricity production by 17 TWh from 2002 to 2016. The electricity certificates can in theory provide an economic benefit to existing solar installations; however, by end 2011 there were only 52 PV installations that have benefited from this measure.

With Sweden's PV subsidy only extended one year at a time this has created uncertainty in the market and difficult conditions for the system installers. A proposal for a monthly net-billing scheme is now being investigated by the government for the third time.

Solarpark Gams, facade integrated PV, Courtesy Heizplan AG, Switzerland

Switzerland (CHE)

Annual installed PV power in Switzerland in 2011 reached over 100 MW – a threefold increase in the annual market compared to the previous year. This was driven by another reduction in the feed-in tariffs (by about 20 %) at the beginning of 2011. Due to this reduction the Federal Office of Energy could significantly increase the yearly cap for PV. During 2011, PV capacity reached about 1,2 % of total national electricity generation capacity. Nearly all the systems installed were distributed grid-connected systems and grid-connected capacity now makes up almost 98 % of Switzerland's cumulative installed PV capacity of 211,1 MW.

The majority of Swiss PV installations are on building rooftops. Larger installations (more than 100 kW) are usually flat-roof mounted on commercial buildings, offices etc. Tilted roof installations on farmhouses with sizes ranging from 30 kW to more than 100 kW have become more common. The size of residential systems has increased from a de-facto standard in earlier years of 3 kW to up to 15 kW. This trend is associated with using the whole roof facing south (SE to SW) rather than only a part of it, as the Swiss feed-in tariff has no upper limits concerning the size of the installation. With decreasing PV costs, east/west facing roofs are also attracting higher interest.

Besides the (capped) national FiT scheme there are many regional, local and utility support schemes operating either with direct subsidies or FiTs equal to or below those offered at the federal level. At the same time, following the failures at the nuclear power plant in Japan, electricity consumers have become more aware of the Swiss electricity mix (40 % nuclear). The events in Japan have also prompted municipalities and local governments to begin to install PV on publicly owned buildings. Local and regional electricity utilities started to design new 100 % renewable energy products with an increasing share of PV and also announced changes in their renewable energy procurement strategies. Naturemade (certified renewable electricity scheme) and the Utility of Zurich (ewz) Solar Stock Exchange continue to operate.

With the Swiss political decision not to replace the existing nuclear power plants at the end of their lifetimes, the perception of PV as a significant potential new source of energy has increased dramatically. Preliminary new federal goals for PV electricity production in Switzerland have been increased to levels of 15 % and more, with PV widely recognized as for having the largest potential amongst new renewable energy sources. Grid parity for residential PV systems is expected before 2015 when tax rebates are included in the calculations and the Plus Energy House is becoming recognized as the building standard of the future. Advanced architects and engineers are already integrating PV and heat pump systems into their building designs for low energy houses.

Turkey (TUR)

About 1 MW of PV was installed in Turkey during 2011, with the annual market remaining at a stable level compared to the previous year. Off-grid applications account for 90 % of Turkey's cumulative installed PV capacity of about 7 MW.

United Kingdom (GBR)

During 2011 899 MW of PV were installed in the UK bringing the cumulative installed capacity to just under 1 GW.

United States of America (USA)

Total PV capacity in the US increased by an estimated 1867 MW in 2011 – representing double the growth in the annual market compared to the previous year, for the second year running. Cumulative installed capacity in the US reached 3 966 MW by the end of 2011. More than 60 000 PV systems were connected in 2011 for a 20 % growth in the number of grid-connected systems installed annually. By the end of 2011, there were approximately 214 000 distributed, grid-connected PV systems installed in the United States; the nation added 770 MW of utility-scale generation capacity that year alone. During 2011, PV capacity reached about 0,4 % of total national electricity generation capacity, with 9,4 % of new electricity generation capacity installed during the year being PV.

2011 was marked by a number of large-scale PV projects, with 28 projects over 10 MW being connected to the grid. These include the first 48 MW phase of the 150 MW Mesquite Solar Project in Arizona, the 38 MW San Luis Valley Solar Ranch in Colorado, the 37 MW Long Island Solar Farm in New York, and the 34 MW Webberville Solar Farm in Texas – all completed in 2011. Further, there were an additional 3 GW of utility-scale projects under construction throughout the year.

The US PV market development is supported by financial incentives at both the federal and state levels; policy drivers for renewable energy deployment remain at the state and local levels. Two of the major federal drivers for growth in the PV market included the 30 % investment tax credit (ITC) and the five-year accelerated depreciation (modified accelerated cost recovery schedule or MACRS). The ITC applies to residential, commercial and utility-scale installations and the MACRS applies only to commercial installations (although it is also indirectly available to the residential systems deployed under a lease or power purchase agreement). For commercial installations, the present value to an investor of the combination of these two incentives (only available to tax paying entities) amounts to about 56 % of the installed cost of the PV system.

In 2011 two additional federal programmes that supported PV expired. A short-term programme allowed owners of non-residential PV properties to receive an up-front 30 % cash grant in lieu of the 30 % federal ITC. As of October 31 2011 the programme had provided 22 060 awards to 870 MW of PV projects. A temporary loan guarantee programme through the Department of Energy (DOE) guaranteed loans for seven PV generating assets, totalling 6,1 BUSD, and four PV manufacturing facilities, totaling 1,3 BUSD.

Over the course of 2011 the federal government outlined the potential for a federal-level clean energy standard that would mandate a certain percentage of the nation's energy portfolio be derived from 'clean' sources. However, to date, a federal level mandate has yet to be implemented. Despite this lack of a national renewable energy policy framework, PV continues to grow rapidly in the US as a result of local and state initiatives.

The diversity of state markets is a source of strength, making it less likely for the US to experience the boom-bust cycles seen in many other national PV markets. California represented 29 % of new capacity installed during 2011 compared to 32 % in 2010, indicating stronger growth in other states. State incentives in the US have been driven in large part by the passage of renewable portfolio standards (RPS), also called renewable electricity standards (RES). As of December 31 2011 16 states and Washington D. C. had RPS policies with specific PV provisions. Several other emergent policy and financing mechanisms have the potential to drive PV market expansion through the establishment of widespread local and utility programmes. Such policies include state-level feed-in tariffs and time-of-use electricity tariff

PV on a former waste dump, Azewijn, The Netherlands

structures. Innovative financing programmes have also been a feature of the US PV market.

Electricity utility interest in PV continues to increase in the US. The key drivers are the 30 % ITC at the national level and renewable portfolio standards at the state level. To date, four broad categories of utility PV business models have emerged in the US: utility ownership of assets, utility financing of assets, development of customer programmes, and utility purchase of PV electricity.

Much of the growth in installed PV capacity, especially in the second half of 2011, came from non-residential and utility-scale installations. PV capacity continues to be concentrated in a small number of states, which include California and New Jersey. With 2,4 GW of PV projects under construction at the end of 2011, installations in 2012 are expected to increase yet again.

Other countries

Verifying total market volume and other data for non IEA PVPS countries is challenging. The following descriptions are not exhaustive. They are intended to give an indication of the scale of a selection of international markets and an overview of market drivers to allow the IEA PVPS data to be viewed in the context of global PV developments. PV is spreading to many new markets, with these countries often following the same policy frameworks as the traditional PV countries. More countries deploying significant quantities of PV should mean a more stable global market development.

Bangladesh
The Government of Bangladesh has been emphasizing the development of solar home systems (SHS) as about half of the population of 150 million has no access to mains electricity. Under the Bangladesh Climate Change Strategy and Action Plan 2009 the government is exploring incentive schemes to encourage entrepreneurs who wish to start PV actions, at present lead by the Infrastructure Development Company Ltd. (IDCOL). Through IDCOL and others about 1,4 million SHS (PV capacity of about 60 MW) have been deployed so far with about 400 000 systems commissioned in 2011. The typical SHS price is 450 USD, a subsidy of 30 USD is provided, and the end user pays a down payment of 10 % to 15 % with the remainder paid as a micro loan with installments over three to five years. The target for 2014 is 2,5 million SHS. IDCOL is also aiming for 10 000 PV irrigation pumps, with a capacity of about 80 MW of PV.

Bulgaria
The Ministry of Economy, Energy and Tourism (MEE) estimates that about 100 MW of PV were installed during 2011, up from about 25 MW the previous year. Bulgaria has set a national target of 2 GW of PV by 2020 and introduced an attractive feed-in tariff. However the annual degression mechanism of the FiT appears non-transparent leading to uncertainties for investors. At end of the previous year (2010) applications totaling about 6 GW had been submitted to grid operators and the tariffs were reduced. The FiT system was revised mid 2011 with tariffs

further reduced, and more dramatic reductions are expected mid 2012. Grid connection procedures are complicated and the process may take up to 18 months.

Czech Republic

Only about 15 MW to 20 MW of PV are estimated to have been installed in the Czech Republic during 2011, down from 1,49 GW in 2010; the total installed capacity amounts to about 2 GW and the market has effectively come to a halt. Initially the Czech Republic had one of the most attractive feed-in tariff schemes in the world at about 12,25 CZK/kWh (about 0,647 USD/kWh) for PV systems up to 30 kW installed capacity and 12,15 CZK/kWh for larger systems – set by the Energy Regulatory Office (ERU), guaranteed for 20 years and funded by a levy on electricity consumer tariffs. Due to the rapid market growth the government has reduced the tariffs to about 50 % of the original values and has retroactively introduced a 26 % to 28 % tax on all PV revenues. Following a transitional scheme up to March 2011, only PV systems of less than 30 kW installed capacity are now included in the feed-in tariff scheme.

Greece

More than 420 MW of grid-connected PV have been installed in Greece during 2011, up from 160 MW in 2010, bringing the cumulative capacity to more than 630 MW. According to the Hellenic Association of PV companies (Helapco) this total capacity may double in 2012. Greece has had an attractive feed-in tariff scheme in operation since 2006 and a current national target of 2,2 GW of PV installed by 2020. At the beginning of 2011 the FiT amounted to 0,55 EUR/kWh for PV roof-tops up to 10 kW and guaranteed for 25 years; for systems up to 100 kW the FiT was 0,42 EUR and for larger systems 0,37 EUR, guaranteed for 20 years. By August 2011 the FiT for systems up to 100 kW was reduced to 0,39 EUR and for larger systems the FiT became 0,35 EUR. Special feed-in tariff conditions are in place for PV systems connected to autonomous island girds. Different conditions with regard to taxation and VAT exist for private households and companies. Permitting procedures were still a barrier during 2011, but are being streamlined.

India

Estimates of total installed PV capacity in India by the end of 2011 range from 400 MW to 600+ MW. The wide range can be explained by the complicated PV plant processing procedures, from sanctioning/allocation for import duty exemption to actual grid connection and commissioning. India's Jawaharlal Nehru National Solar Energy Mission (JNNSM) sets out ambitious targets for PV capacities – 20 GW in 2022 and 100 GW in 2030, with 90 % being grid-connected systems and 10 % off-grid systems.

The Ministry of New and Renewable Energy (MNRE) estimates India to have installed about 450 MW of grid-connected PV power, with about 153 MW occurring under the JNNSM. Gujarat has about 185 MW of PV installed, Rajastan 120 MW and a number of other states between 1 MW and 18 MW. Off-grid PV amounts to about 60 MW installed by the end of 2011– up from 50 MW by the end of 2010. These applications include PV lanterns, solar home systems, streetlights, police stations, telecom towers and small water pumping systems.

The government has introduced an indicative FiT, guaranteed for 25 years, amounting to 0,4 USD/kWh but has combined this with a 'blind bidding' process in which applicants nominate their own discounted FiT. The blind bidding process appears to lead to discounts of 25 % to 35 % below the announced FiT. The central government has additional support schemes for PV deployment, for example the migrations scheme at the Central Energy Regulatory Commission (CERC) and the IREDA Small Solar and Rooftop Programme. A second bidding process capped at 350 MW was launched in August 2011 and resulted in letters-of-intent for 22 selected bidders and 28 projects four months later. Also a number of PV projects totaling around 45 MW have been selected under the JNNSM migration scheme at the CERC.

The respective roles and responsibilities of the central and local governments are not well defined. The states of Rajastan and Gujarat appear to have their own very ambitious plans for PV, for example Rajastan with a current target of 500 MW and 10 GW by the end of 2014.

Romania

By end of 2011 the cumulative installed capacity reached about 2 MW. During 2011 Romania introduced a scheme of green certificates, which for PV works out in the range of 0,33 EUR/kWh to 0,16 EUR/kWh, guaranteed over 15 years. This measure is expected to kick-start the PV market in the country and increase the installed capacity one hundredfold in 2012, but the Romania Energy Regulatory Authority may limit the growth rate if it is found to be excessive.

Slovakia

During 2011 the installed capacity in Slovakia grew from 147 MW to around 468 MW. In January 2010 the government introduced a feed-in tariff scheme guaranteed for 15 years; the scheme is adjusted to developments in PV prices and in 2011 was reduced twice. At the beginning of 2011 the FiT ranged from almost 0,52 EUR/kWh for fully integrated roof-top systems to 0,34 EUR/kWh for ground based installations. For installations larger than 100 kW there was a quota of 120 MW (already exhausted in 2010). Consequently FiT support has been limited to installations less than 100 kW installed capacity.

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

Slovenia
The amount of installed PV capacity in Slovenia appears to have grown from around 35 MW in 2010 to almost 85 MW by the end of 2011. In June 2009 Slovenia introduced a new 15-year feed-in tariff scheme with differentiated prices and an annual degression rate of 7 %. The FiT scheme was revised in 2011, applying a system cap of 10 MW/system, and by end of 2011 the FiT ranged from 0,38 EUR/kWh to 0,23 EUR/kWh. Further reductions are expected.

Taiwan
During 2011 Taiwan installed about 10 MW of PV, mostly in the form of grid-connected roof-top installations. By the end of 2011 the cumulative installed PV capacity was about 30 MW. Taiwan has a feed-in tariff scheme for PV, guaranteed for 20 years, administered by the Bureau of Energy, Ministry of Economic Affairs. This is part of the Renewable Energy Development Act (REDA) passed in mid 2009. Initially the feed-in tariff was quite generous at 0,50 USD/kWh (0,38 USD/kWh if combined with the capital subsidy of 1 700 USD/kW available to property owners), but it was later reduced to about 0,35 USD/kWh, applied only to property owners, with system sizes capped at 10 kW. Larger systems and ground-based systems have to be approved in a competitive bidding process based on the lowest feed-in tariff offered. Furthermore an annual ceiling has been introduced – to be adjusted every two years – 10 MW for systems up to 10 kW and 60 MW for larger systems, for a total annual cap of 70 MW. Property owners can receive a further capital subsidy of about 1 700 USD/kW installed. It is the intention to favor small-scale roof-top PV at the expense of larger-scale systems, particular ground-based installations.

Thailand
By the end of 2011 Thailand had a cumulative installed PV capacity of about 160 MW to 180 MW, with about one third being off-grid systems. The amount of operational off-grid systems is somewhat uncertain. The annual market during 2011 was about 100 MW to 120 MW, mostly large grid-connected systems. A number of PV farms are under construction totaling about 160 MW – with expansion plans up to almost 400 MW - including a 73 MW PV plant.

Thailand is aiming for a renewable energy contribution of 20 % by 2022. In 2009 a feed-in tariff for PV was introduced in the form of an additional 8 THB/kWh (about 0,26 USD/kWh) on top of the regular tariff of around 3 THB/kWh. The feed-in tariff is guaranteed for ten years and is paid by a small levy on the price of electricity. Other PV support schemes include tax incentives by the national Board of Investment, free technical assistance, investment grants, soft loans and a government co-investment scheme. Thailand initially targeted 500 MW of PV capacity by 2020, but has – according to the Ministry of Energy – already received applications for almost 3 GW. In late November 2011 the National Energy Policy Commission approved a 10-year Alternative Energy Development Plan 2012-21 raising the PV target to 2 GW; the plan has yet to be minted into policy.

Previously, Thailand put the deployment of grid-connected PV systems on hold, while deliberating how to control the future development of the PV market without penalizing the ordinary electricity consumer with price hikes. The ‘adder’ has been reduced from 8 THB/kWh to 6,5 THB/kWh. It is expected that Thai PV policy in the future will focus more on PV roof-top systems and other smaller PV applications.

Recent country news
In the Latin American countries about 15 MW to 20 MW of PV were in operation at the end of 2011, with about 100 MW reported to be under construction. Almost 2 GW of ‘new’ projects were announced. **Brazil** has about 30 MW of PV capacity installed of which only about 5 % is grid connected. No direct support schemes for PV existed in 2011, however there are certain tax exemptions and several states are studying or preparing for support schemes for PV. Electricity utility Electrobras is preparing for grid-connected PV systems and is looking for suitable institutions, companies and developers to partner with. **Uruguay**, in 2010, introduced the first net-metering regulation in South America and has subsequently announced that it is preparing a FiT of about 0,12 USD/kWh. **Peru’s** energy regulator (OSINERGMIN) awarded 80 MW of grid-connected PV capacity in 2010 following a blind bidding procedure with a ceiling of 0,269 USD/kWh but no PV systems appear to have been commissioned in 2011 (although 40 MW are reported to be under construction with a further 15 MW to 20 MW under contracting). Grid-connected PV is also being

Rooftop installation in bern, Switzerland, Photo: BE Netz AG introduced in **Argentina**, **Chile** and **Columbia**, with Chile considering setting up a regulatory framework for a net-metering scheme.

Although the installed PV capacity, particularly grid-connected, in the MENA countries is still quite low, there is a clear trend across the region to include PV in energy planning, to set national targets for PV and to prepare a regulatory framework to accommodate PV. An increasing number of flagship projects are being announced. **Morroco** has launched a 2 GW Solar Plan with a dedicated implementing agency; PV and CSP technologies are expected to compete openly in this context, and export of solar electricity to Europe is foreseen. By end of 2011 about 16 MW of PV are estimated to have been installed, of which 15 MW are small SHS providing electricity to some 50 000 off-grid homes. In the **United Arab Emirates** the MASDAR initiative is moving ahead targeting an extensive deployment of PV, although the global economic crisis appears to have lead to a postponement of targets. **Saudi Arabia** has drafted a master solar energy plan aiming for about 40 GW of solar power by 2032, of which 15 GW is expected to be PV. The Kingdom is reported to have set a target of 5 GW of solar power inside a decade, and it appears the country aspires to export solar electricity to neighboring countries and international markets given the advances in low-loss electricity transmission. **Oman** has established a renewable energy strategy including PV and is presently – following international tenders – installing PV systems in support of the many diesel-powered mini-grids in the country. Late in 2011 it was announced that foreign and domestic investors planned a 2 BUSD project to develop 400 MW of PV installations and local PV manufacturing facilities. **Egypt** has set a target of 20 % renewable energy by 2020, and both CSP and PV are expected to contribute to reaching this target. **Dubai** has initiated a PV project, aimed at eventually reaching 1 GW installed capacity; the first phase of 10 MW is expected to be completed by 2013. Both **Algeria** and **Jordan** are developing ambitious solar energy and PV plans and Jordan is preparing a renewable energy fund. **Bahrain** is planning a 5 MW PV project.

South Africa is rolling out plans for a 5 GW solar park in Upington; however this is separate to the Department of Energy's Integrated Resource Plan 2 (IRP2010) on electricity planning up to 2030 that mentions a target of 600 MW of PV by 2019. This target is expected to be increased. In late 2011 the first round of the DoE's competitive bidding programme recommended 20 developers, to provide almost 800 MW of solar power capacity of which about 630 MW will be PV. The output of the PV plants, ranging from 5 MW to 100 MW will be bought by electricity utility ESKOM under PPA arrangements. A second bidding round is expected mid 2012 maybe targeting an additional 400 MW of PV. In 2010 two PV farms of 2,5 MW and 5 MW were connected to the grid in the archipelago state of **Cape Verde** covering about 4 % of the national electricity consumption. **Uganda** has – probably as the first country in Africa – introduced a Renewable Energy Feed-in Tariff (REFIT) programme under the administration of the Electricity Regulatory Authority. The REFIT programme includes wind energy, geothermal energy, biogas and landfill gas and PV; for PV the tariff is 0,36 USD/kWh for 20 years. **Angola** has announced about 530 kW of off-grid PV to be installed in rural areas. **Botswana** is implementing a 1,3 MW PV plant with support from Japan. **Kenya** has issued tenders for PV systems to support existing diesel mini-grids. **Namibia** has completed a 200 kW PV-diesel mini-grid system. **Mozambique** is developing PV plants in the range of 400 kW to 500 kW.

All installations reported in 2011 for non-reporting countries amount to around 2200 MW, according to industry numbers and estimates. This would put the total installed capacity added in 2011 in the entire world to slightly more than 30 GW (Estimation EPIA).

1.4 R&D activities and funding

The public budgets for research and development in 2011 in the IEA PVPS countries are outlined in Table 4. While several countries have reported a significant increase of expenditure in 2011 compared to 2010, most countries maintained the same scale of public budgets with some increases and some decreases. It is interesting to note that while a significant cost reduction of PV applications has been observed, grid-parity and sustainable markets are rapidly approaching and PV is now being regarded as a mainstream electricity supply option, governments are clearly identifying the benefits of further development of the technology, better integration with existing energy systems and the benefits of new innovations.

Table 4 – Public budgets for R&D in 2011 in selected IEA PVPS countries

Country	Million EUR	Million USD
AUS	22,5	31,2
AUT	5,2 (2009)	6,8 (2009)
CAN	7,1	9,9
DEU	>56	>77,8
DNK	3,4	4,7
FRA	80 (for 3–5 years)	111,1 (for 3–5 years)
ISR	0,6	0,8
ITA	5,8	8,1
JPN (METI)	73,4	102
KOR	67,6	93,9
NDL	17,8	24,7
SWE	6,8	9,4
USA	160,5	222,9

The most significant reporting countries in terms of R&D funding are the US, Germany, Korea, Japan, Australia and France. China also reported various ongoing programmes. The reader is directed to the individual national survey reports on the public website for a comprehensive summary of R&D activities in each of the countries. A brief overview of the R&D sector in key countries is presented below.

The US is a clear leader in terms of R&D public funding for PV. DOE accelerates the research, development, and deployment of all solar energy technologies through its Solar Energy Technologies Programme (SETP). In February 2011, DOE launched the SunShot Initiative, a programme focused on driving innovation to make solar energy systems cost-competitive with other forms of unsubsidized energy. To accomplish this, the DOE is supporting efforts by private companies, academia, and national laboratories to drive down the cost of solar electricity to about 0,06 USD/kWh. This, in turn, would enable solar-generated power to account for 15 % to 18 % of America's electricity generation by 2030. By funding selective R,D&D concepts, the SunShot Initiative promotes a genuine transformation in the ways the US generates, stores, and utilizes solar energy. SETP-funded research and development activities include the following: demonstration and validation of new concepts in materials, processes, and device designs; R,D&D of balance of system components; applied scientific research that provides the technical foundation for significant increases in solar PV cell efficiency, to enable commercial and near-commercial PV technologies to achieve installed system cost targets of 1 USD/W direct current by the end of the decade; and the Rooftop Solar Challenge, an initiative in which cities, states, and regions are awarded funding to develop innovative ways to drive measurable improvements in market conditions for roof-top PV across the US, with an emphasis on streamlined and standardized permitting and interconnection processes.

In Germany, R&D is conducted under the new 6th Programme on Energy Research 'Research for an environmental friendly, reliable and economical feasible energy supply' which came into force in August 2011. Within this framework, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Ministry of Education and Research (BMBF) support R&D ranging from basic research to applied research on almost all aspects of PV. 2011 PV research funding showed a significant increase, particularly due to the implementation of the Photovoltaics Innovation Alliance, a joint programme of BMU and BMBF, launched in 2010 to promote a significant reduction of PV production costs. In 2011, a total of 96 new projects were approved (2010: 45 projects), with a total funding volume of around 74 MEUR, compared with just under 40 MEUR in 2010. In 2011, a total of 39 MEUR was allocated to on-going projects, on a par with the previous year. BMU research funding priorities are silicon wafer technology, thin-film technologies, systems engineering, alternative solar cell concepts and new research approaches (such as concentrating PV), as well as general issues such as building-integrated photovoltaics, recycling, and accompanying environmental research projects. Activities of the BMBF have three focal points: organic solar cells, thin-film solar cells (with the emphasis on topics such as material sciences including nanotechnology, new experimental or analytical methods), and the cluster called 'Solarvalley Mitteldeutschland' in which most of the German PV industry participates.

Korea Energy Technology Evaluation and Planning (KETEP) has played a leading role in Korea's PV R&D programme since 2008. The R&D budget tripled in 2008 compared with 2007, showed a 20 % increase in 2009, and increases of 12 % and 24 % in 2010 and 2011 respectively. In 2011, 42 new and 51 continuing projects are organized under four R&D sub-programmes – Commercialization Technology Development, Strategic R&D, Basic & Innovative R&D and Short-term Core Technologies Development for Medium and Small industry. The R&D budget for the 42 new projects amounts to 47,2 MUSD. The sub-programme Basic & Innovative R&D is led by research institutes or universities, and the other three sub-programmes are led by industry. An example of Commercialization Technology Development projects funded in 2011 is 'Development of high-efficiency and large-area thin-film PV modules' that focuses on CIGS and silicon-based thin-film technologies.

Japan reported various activities concerning PV R&D. The New Energy and Industrial Technology Development Organization (NEDO) conducted national PV R&D programmes, 'R&D on Innovative Solar Cells' and 'R&D for High Performance PV Generation System for the Future' with funding from the Ministry of Economy, Trade and Industry (METI). The Ministry of Education, Culture, Sports, Science and Technology (MEXT) continued two programmes, Photoenergy Conversion Systems and Materials for the Next Generation Solar Cells, and Creative Research for Clean Energy Generation using Solar Energy. In addition, 'Development of Organic Photovoltaics toward a Low-Carbon Society' continues to be conducted by the University of Tokyo. With the third national supplementary budget for recovery and reconstruction of the damaged regions associated with the Great East Japan Earthquake, the Japanese government allocated a budget for the development of new research facilities in Koriyama, Fukushima Prefecture. The Research

South Gate Square, Daejeon, Korea

Center for Photovoltaic Technologies (RCPVT) at the National Institute of Advanced Industrial Science and Technology (AIST) is leading the preparation work for the new facilities that will focus on crystalline silicon PV cells and system demonstration research. In addition, work on high-performance PV cells is planned, as part of an R&D programme on next-generation energy for the reconstruction of the earthquake-affected area, principally led by the Japan Science and Technology Agency (JST).

In Australia, PV research, development and demonstration are supported at the national, as well as the state and territory levels. Research grants are available through the Australian Research Council and the Australian Solar Institute (ASI). ASI invested over 4 million AUD in 2011 on PV research ranging from third generation and organic solar cells to forecasting and grid integration of PV. In 2011, the Australian Government launched its Clean Energy Initiative, which will see all R&D support for renewables placed under the Australian Renewable Energy Agency (ARENA) from 2012. Industry funding for technology development was also available through the Australian Centre for Renewable Energy.

French R&D programmes are mostly funded by public agencies: ADEME (French Environment and Energy Management Agency), ANR (French National Research Agency) and OSEO (organisation providing financial support to French companies for start-up, innovation and development projects). Within the National Future Investment programme (PIA), ADEME selected 14 pre-industrial demonstration projects (AMI PV: 8 projects and AMI Solaire: 6 projects). Selected AMI PV projects cover research and development of silicon feedstock, crystalline silicon process, thin-films, and concentrator photovoltaic (CPV) modules. The ANR launched the three-year PROGELEC research programme (renewable electricity production and management) in early 2011. The 'Photovoltaic electricity production' theme selected five research projects. The new three to five-year R&D projects will receive support from ADEME and ANR (refundable advances and subsidies) amounting to around 80 MEUR.

China reported various R&D activities on crystalline silicon solar cells, thin-films, concentrator solar cells and system integration. While the magnitude of the budget is not reported, China has been conducting PV R&D under the National High-tech R&D Programme (863 Programme) since 1986 and basic research related to PV under the National Basic Research Programme (also called the 973 Programme). The Ministry of Science and Technology (MoST) supports the key technologies in storage, transmission demonstrations of PV and wind power generation. Under China's 12th Five Year Plan (2011–2015) major R&D projects are planned to facilitate breakthroughs in all areas, to promote significant growth in PV power generation. Targets for PV cell development by 2015 are development of greater than 20 % and 10 % conversion efficiencies for crystalline silicon solar cells and silicon-based thin-film solar cells respectively, and also the commercialization of CIGS and CdTe thin-films. Other projects are also planned in the areas of polysilicon production, devices, equipment, materials, components and systems. Demonstration of a 100 MW grid-connected PV power station, 10 MW PV micro-grid and regional 10 MW building-related PV applications are also planned. In addition to these projects, the national 973 Programme will support R&D on the next generation of super-efficiency, new concept PV cells with 40 % conversion efficiency.

The European Commission promotes PV research and development under the European Union's 7th Framework Programme (FP7). 2011 marked the fifth year of the FP7 that 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. With the first five calls launched under the FP7, more than 172 MEUR have already been invested. Development of materials for longer-term applications, concentration PV and manufacturing process improvement have attracted considerable European funding. Furthermore, significant funding has been made available for thin-film technology.

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 2011. 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 2011 is presented in Table 5 and is directly based on the information provided in the national survey reports.

Manufacturers across the PV value chain experienced a difficult year in 2011, notwithstanding the increase in total production of PV cells and modules. Uncertainty about the incentive programmes in major PV markets created stagnant conditions in the first half of 2011, while PV manufacturers maintained a relatively high level of capacity utilization. This caused an increase of inventory and resulted in price reductions across the value chain. The tight business environment forced PV manufacturers to adjust or review their production plans and/or undertake business restructuring. A number of PV manufacturers in IEA PVPS member countries filed for insolvency. The macroeconomic environment (especially in Europe) and tighter access to investment capital have only served to accelerate these trends. In a highly competitive environment, the PV companies have been focusing on differentiation of products, cost structures, business models and customer portfolios to address lower margins. Several parties from upstream sectors entered downstream businesses including EPC or project development to secure their profits. There were also acquisitions of companies to enhance downstream business.

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

Table 5 – Reported production of PV materials, cells and modules in 2011 in selected IEA PVPS countries

Country ***(1)***	Solar PV Grade Si Feedstock production (tonnes)	Production of Ingots (tonnes)	Production of wafers (MW)	Cell Production (all types, MW)	*Cell production capacity (MW/year)*	Module production (MW) ***(2)***		
						wafer based (sc-Si & mc-Si)	thin film (a-Si & other)	*Module production capacity (MW/year)*
AUS	–	–	–	4	50	4	–	38
AUT	–	–	–	–	–	156,6	–	> 156,6
CAN	NA	–	–	–	–	158	–	> 158
CHE	–	900	approx. 120	–	–	approx. 5	–	40
CHN	84 000	–	24 500	11 528 **(3)**	17 804 **(3)**	10 090 **(4)**	450	16 514
DEU	37 150	1 200	2 270	2 919,2	4 152,5	2 302	768,2	3 472
FRA	NA	**(5)**	NA	NA	70 **(6)**	NA **(7)**	NA **(7)**	470
ITA	–	–	308	118	250	413	–	882
JPN	3 754	2 696	361	2 725,5	> 2 806,5	1 798,6	749,6	5 173,7
KOR	40 000	–	1 800	1 030	1 830	1 700	–	2 700
MYS	–	–	600	NA **(8)**	1 020	NA **(8)**	NA **(8)**	2 073
PRT	–	–	–	–	–	80,3	~ 5,5	294
SWE	–	–	–	–	–	40,5	–	222,5
USA	40 658	–	360	1 056	1 822	786	547	2 339

Notes:
(1) Although a number of IEA PVPS countries are reporting on production of feedstock, ingots and wafers, cells and modules, the picture from the national survey reports of the PV industry supply chain is by no means complete and consequently these data are provided more as background information.
(2) mc-Si (multicrystalline silicon) includes modules based on EFG and String Ribbon cells. 'Other' refers to technologies other than silicon based. The total module production and module production capacity data for some countries were not available.
(3) Included c-Si based cell figures are only from top 10 manufacturers. Estimated total cell production in China in 2011 is 20GW.
(4 Included figures are only from top 10 manufacturers and 2 major thin-film manufacturers.
(5) Production capacity is 1 360t/yr.
(6) Figures include only industrial production capacity of silicon PV cells.
(7) Module production is not available.
(8) Production of cell and module is not available.

processes. Switzerland provides an excellent example of the economic significance of this section of the PV industry. However, the competitive business environment for PV cell and module manufacturers also affected these players in 2011. Additionally, as a consequence of global overcapacity and lower margins within the PV industry, investors and financiers have become increasingly selective.

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 reported on production of feedstock, ingots and wafers, the pictures from the national survey reports of these sections of the PV industry supply chain are not complete and consequently this section is provided more as background information.

Feedstock

To meet the increasing demand for crystalline silicon for PV cells, established manufacturers of polysilicon for semiconductors increased their production capacity to supply the solar industry. A number of new entrants from China and Korea also raised their production capacity. It is understood that total the production capacity of polysilicon is almost double the actual global demand for crystalline silicon PV cells, and due to the price pressure, the spot price of polysilicon dropped from about 70 to 80 USD/kg in January 2011 to 25 to 28 USD/kg in December 2011. Polysilicon manufacturers are focusing on lowering their manufacturing costs to secure profits.

Most of major manufacturers have adopted conventional technologies such as Siemens and FBR processes, which were used to supply silicon for the semiconductor industry. New technology such as the metallurgical process has not yet become a major force for the supply of silicon for PV cells, mainly due to the quality of the silicon.

In 2011, polysilicon for PV cells was mainly manufactured in China, the US, Korea, Germany and Japan, with smaller levels of production in Canada and Norway. China produced 84 000 tonnes of polysilicon, a 87 % increase from the previous year and reported 165 000 t/yr of production capacity in 2011. Meanwhile, China imported 64 600 tonnes of polysilicon, a 36 % increase from the previous year. The US produced 40 658 tonnes, a slight decrease from 2011 (42 561 tonnes). Korea significantly increased polysilicon production capacity to 57 800 t/yr from 36 200 t/yr in 2010 and produced 40 000 tonnes. Among the four Korean producers, OCI is the largest producer with 40 000 t/yr of capacity. Germany produced 3 754 tonnes of polysilicon with a production capacity of 44 030 t/yr, a 23 % increase from the previous year. In Japan, 3 754 tonnes of polysilicon were produced by Tokuyama and M.Setek. Tokuyama started construction of a plant in Malaysia and plans to start operation of the first phase of the plant in June 2013.

Affected by the price reduction trends, several producers with relatively small production capacity or newly developed processes were forced to halt production. New feedstock manufacturing facilities are planned in several member and non-member countries, but some potential entrants are expected not to proceed in consideration of the overcapacity of polysilicon with respect to current and near-term demand.

Manufacturing capacities are also reported to be growing for the raw materials for thin-film PV cell technologies. Canada reported production of high purity compounds for CdTe thin-film PV cells. Monosilane gas for thin-film silicon PV modules is produced in several member countries including the US and Japan.

Ingots and wafers

To make single crystalline silicon ingots, multicrystalline silicon ingots or multicrystalline silicon ribbons, the basic input material is highly purified polysilicon. 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. Conventional 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. In addition, quasi-mono products that have fewer grain boundaries compared to multicrystalline, are being commercialized by Chinese producers. Ingot producers are in many cases also producers of wafers.

China, as the world's largest producer, reported production of solar wafers amounting to 24,5 GW, with GCL-Poly Energy and LDK Solar together contributing 17 % of global production. Other major wafer producing countries amongst IEA PVPS members are Germany, Korea, Malaysia, Japan and the US – and to a lesser extent Italy, Switzerland, France and the UK. Germany produced 24 500 MW, a 23 % increase from 2011. Korea increased production to 18 000 MW in 2011 from 800 MW in 2010. Malaysia reported 600 MW of wafer manufacturing in 2011 with a new production facility established by MEMC of the US. Japan reported 361 MW of wafer production, a 46,7 % decrease from 2011. The US also reported a decrease of wafer production to 360 MW in 2011 from 542 MW in 2010.

It is reported that crystalline silicon wafer prices dropped 41 % during 2011 and some companies were forced to restructure their production frameworks, downsize or withdraw from the business. One of these examples is REC Corporation of Norway. REC announced the closure of its Norwegian wafer manufacturing facilities and shifted its production to Singapore. In non-PVPS countries, Taiwan is a major producer of solar wafers with more than 3 GW of production capacity.

2.2 Photovoltaic cell and module production

Total PV cell production for 2011 in the IEA PVPS countries is estimated to be 29,9 GW, about a 70 % increase from the previous year. China was the largest producer of PV cells in 2011 with estimated production of about 20 GW. This is almost double the estimated production in China for the previous year. China reported that its top ten crystalline silicon PV cell producers manufactured 11,5 GW of cells in 2011 and it is noteworthy that nine of these companies have GW-scale production capacity (two have more than 2 GW of production capacity – JA Solar with 2,8 GW/yr and Suntech Power with 2,4 GW/yr).

Other PVPS countries having achieved GW-scale production include Germany with 2,5 GW, Japan with 2,7 GW, Malaysia with an estimated 2 GW, Korea with 1 GW, and the US with 1,1 GW. Australia, France and Italy also reported production of PV cells. In 2011, the IEA PVPS countries account for around 80 % of the global PV cell production. Taiwan produced 4,3 GW of PV cells. Other major non-PVPS countries manufacturing PV cells are the Philippines, Singapore and India.

The picture for PV module production is similar to that for cell production. About 34 GW of wafer based and thin-film modules were produced in the IEA PVPS countries in 2011. Total module production in the IEA PVPS countries increased by 71 % in 2011. Again, the largest producer was China delivering about 21 GW, a 141 % increase compared with last year, and contributing more than 60 % of global production. Other major IEA PVPS countries that reported GW-scale PV module production were Germany 2,3 GW, Japan 2,5 GW, Malaysia an estimated 2 GW, Korea 1,7 GW and the US 1,3 GW. Australia, Austria, Canada, Denmark and Sweden also reported module production. In total, the PVPS countries produced approximately 30 GW of wafer based modules and 3,9 GW of thin-film modules. PV module production in PVPS countries accounted for more than 90 % of the modules produced globally in 2011. Estimated utilization of capacity in 2011 was about 70 %, much the same level as during the previous year. The module production capacity in the IEA PVPS countries increased to 48 GW (up by 52 %) in 2011. China contributed significantly to this growth, increasing from 15 GW/yr in 2010 to 30 GW/yr in 2011.

Thin-film PV modules are mainly produced in Germany, Japan, Malaysia, the US and China. The US reported that 20 producers manufactured a total of 547 MW of thin-film PV modules in 2011, including CdTe, CIGS and thin-film silicon. Among the US thin-film PV manufacturers, First Solar produced 1 981 MW of CdTe PV modules in its factories in the US, Germany and Malaysia in 2011, and is ranked as the largest thin-film PV module producer in the world.

In Japan, 750 MW of thin-film PV modules are produced. Sharp produced 220 MW of thin-film silicon PV modules. Solar Frontier achieved 980 MW/yr of manufacturing capacity and produced 450 MW of CIS PV modules. Germany reported 768,2 MW of thin-film PV module production. In China, 450 MW of thin-film silicon PV modules were produced by Hanergy and Trony Solar in 2011. Hanergy has 1,5 GW/yr of production capacity in total.

Thin-film PV manufacturers are struggling to compete with the costs of crystalline silicon PV products. A number of companies with smaller production capacity and also new entrants trying to raise

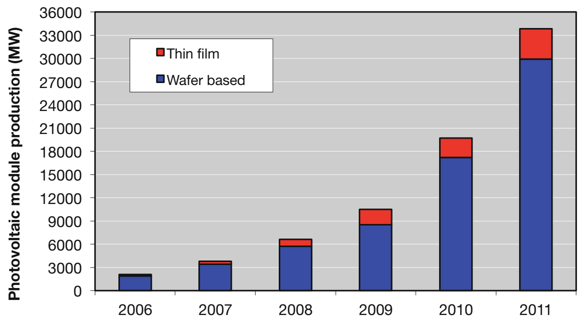

Figure 4 – Trends in photovoltaic module technologies in the IEA PVPS countries 2006–2011

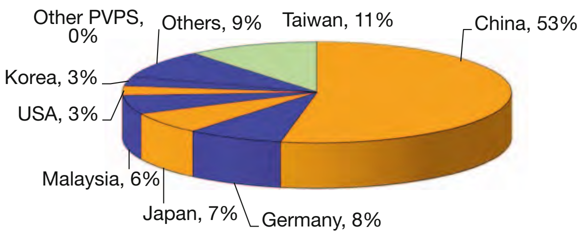

Figure 5 – Estimated world PV cell production (%) by country in 2011

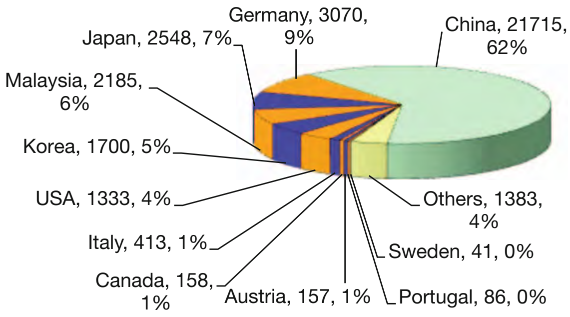

Figure 6 – PV module production (MW) by reporting IEA PVPS country in 2011

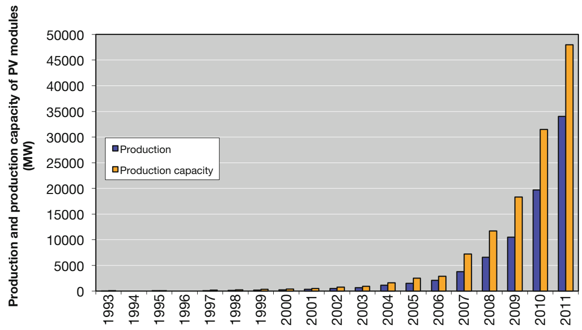

Figure 7 – Yearly PV module production and production capacity in the IEA PVPS reporting countries

their production capacity reviewed their plans and restructured their businesses. Some companies announced their withdrawal from the PV business. However, R&D and commercialization of CIGS PV modules are continuing in a number of IEA PVPS member countries, aiming for higher conversion efficiencies and higher throughput.

In 2011, concentrating PV (CPV) cell/modules are reported from several member countries. The technology is mainly based on specific PV cells using group III-V materials, such as GaAs, InP, etc. Germany reported 5 MW of CPV cell production with 30 MW/yr production capacity. Australia reported pilot production of 0,05 MW of CPV modules by Solar Systems. The US and France are also active in this area. The US reported that a total of 12 MW of grid-connected centralized PV applications using CPV technology was installed in 2011.

In 2011, significant changes were observed in the global PV business environment. The global PV market largely shifted from a seller's market to a buyer's market due to continued excess capital investment in production capacity, larger than the growth of the demand for the products. PV prices declined because of supply and demand gaps rather than the previously experienced effects of mass production and R&D efforts. PV module prices dropped to around 1 USD/W from 2 USD/W or higher in one year. The market share of the world's top ten PV manufacturers decreased to below 50 %, a large decline from the 70 % to 80 % levels of the past. This represents much increased competition in the industry. The business environment for PV manufacturers has changed from a high-profit structure to a low-profit structure, in which the majority of manufacturers go into the red. However, significant price reductions contributed to an increased competitiveness of PV power and PV is now becoming feasible in the regions where it was previously regarded as too expensive.

Key issues identified in 2011 include:

- an increase in the number of GW-scale manufacturers. PV manufacturers with production capacities of between 1 GW and close to 3 GW emerged, mainly in Asia. A number of manufacturers suffered decreased utilization of capacity.
- supply and demand gaps widened and resulted in price reductions at all levels of the value chain. Due to the widening gap between capacity and demand, manufacturers halted their enhancement plans or downsized their production capacity. Some companies filed for insolvency.
- while manufacturers are suffering from lower margins, price reductions contributed to increased competitiveness of PV power against conventional energy sources.
- emergence of GW-level supply capabilities for PV in the areas of materials, components and BOS, and emergence of gaps between supply and demand.
- advancement of a partnership approach to enhance the PV business. In the area of manufacturing equipment, as well as upstream and downstream industries, the following activities were noted: 1) business expansion through acquisitions of companies in the same industry segment, and partnerships 2) securing of raw materials through entries into upstream industries 3) securing of distribution channels through entries into downstream industries 4) establishment of vertically-integrated production frameworks 5) partnerships to accelerate R&D and development of new products.

A trade issue concerning PV products emerged during 2011, with ongoing repercussions. In the US, an industry group filed a petition to instigate anti-dumping procedures against PV modules using PV cells made in China. The US Department of Commerce (DoC) investigated and made a preliminary decision to impose duties on PV products using PV cells made in China. In July 2012, China

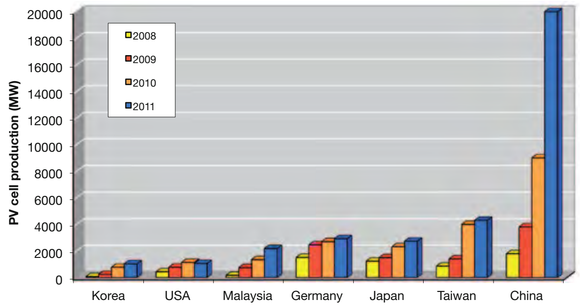

Figure 8 – Evolution of the PV industry in selected countries – PV cell production in 2008, 2009, 2010 and 2011

started investigations related to dumping of polysilicon made in the US and Korea. A group of European manufacturers petitioned the European Commission to investigate dumping of Chinese modules on the European markets. The concern is that such retaliatory actions can spiral in such a way as to negatively affect the health of the global PV market.

2.3 Balance of system component manufacturers and suppliers

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

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

In Europe the major PV inverter companies are located in Germany, Spain, Austria, Switzerland, Denmark and Italy. European companies are extending their sales bases in the emerging markets. Outside Europe, activities in this field are reported from Japan, the US, Korea, Canada and China. In Japan, about 20 manufacturers are producing inverters. The US produced 1,6 GW of inverters and had 7,3 GW of manufacturing capacity at the end of 2011. In the US the share of micro-inverters is increasing and its market share in California for residential installations reached more than 30 % at the end of 2011. In Korea, more than eight companies are involved in the inverter business. In Canada, a number of inverter manufacturers have established manufacturing bases to address local content requirements implemented by the Province of Ontario. China reported that 53 inverter manufacturers are certified by the China Quality Certification Center. Chinese manufacturers cover a wide range of products from small to large capacity, including 1 MW centralized application inverters. With the growth of the domestic PV system market, Chinese manufacturers reported more than 30 GW/yr of production capacity. New market players and increased production have been reported from non-PVPS countries, particularly Taiwan, supporting the trend towards a further price reduction of the products.

The inverter supply shortage that was observed globally in 2010 softened in 2011 with the increase of production capacity. 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 (the US and Japan) grid-connection. For larger systems, PV inverters are usually installed in a 3-phase configuration with typical sizes of 10 kW to 250 kW. With the increasing number of utility-scale PV systems in the MW range, larger inverters have been developed with rated capacities up to 2,5 MW.

Production of specialized components, such as PV connectors, DC switchgear and monitoring systems, is an important business for a number of large electric equipment manufacturers. Dedicated products and solutions are now also available in the utility-scale power range. Along with product development of Home Energy Management Systems (HEMS) and Building Energy Management Systems (BEMS), package products consisting of ‘storage batteries, new and renewable energy equipment and PV systems’ are now on the rise.

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 more than 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 2011 the lowest system prices in the off-grid sector, irrespective of the type of application, typically ranged from about 3,7 USD/W to 7,2 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 approximately 7,5 USD/W, about 7 % less than the corresponding average price reported for 2010.

The lowest achievable installed price of grid-connected systems in 2011 also varied between countries as shown in Table 6. The average price of these systems was around 3,6 USD/W, about 17 % lower than the average 2010 price. Prices as low as around 2 USD/W were reported; typically prices were in the range of 2,6 USD/W to 4,4 USD/W. Large grid-connected installations can have either lower system prices depending on the economies of scale achieved, or higher system prices where the nature of the building integration and installation, degree of innovation, learning costs in project management and the price of custom-made modules may be significant factors.

On average, the cost of PV modules in 2011 (shown in Table 7) accounted for approximately 50 % of the lowest achievable prices that have been reported for grid-connected systems. In 2011 the average price of modules in the reporting countries was about 1,38 USD/W, a decrease of almost 50 % compared to the corresponding figure for 2010, following a decrease of 20 % the previous year. Most but not all reporting countries recorded lower module prices than in 2010. Two countries reported module prices less than 1 USD/W; half of the lowest achievable prices fell within the range of 1 USD/W to 1,5 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 6 – Indicative installed system prices in reporting countries in 2011

Country	Off-grid (EUR or USD per W)				Grid-connected (EUR or USD per W)			
	<1 kW		>1 kW		<10 kW		>10 kW	
	EUR	USD	EUR	USD	EUR	USD	EUR	USD
AUS	**4,5–11,1**	6,2–15,5	**5,2–14,8**	7,2–20,6	**2,2–3,0**	3,1–4,1	**1,9–3,0**	2,6–4,1
AUT	**≤10**	≤13,9	**≤10**	≤13,9	**2,5**	3,5	**<2,5**	<3,5
CAN			**9,4**	13,1	**4,9**	6,9	**2,5–3,8**	3,5–5,3
CHE					**4,0–4,9**	5,6–6,7	**2,4–3,2**	3,4–4,5
CHN					**2**	2,7	**2**	2,7
DEU					**2–2,5**	2,8-3,5	**1,8**	2,5
DNK	**2,7–4,7**	3,7–6,5	**4,7–8,1**	6,5–11,2	**2,4–4,0**	3,4–5,6	**1,3–5,4**	1,9–7,5
FRA					**3,9**	5,4	**2–2,6**	2,8–3,6
ISR	**5,0**	7,0	**5,0**	7,0	**2,5**	3,5	**2,2**	3,0
ITA	**5–7**	6,9–9,7			**3–3,4**	4,2–4,7	**2–3**	2,8–4,2
JPN					**4,7**	6,5	**4,7**	6,5
KOR					**2,6**	3,6	**2,0**	2,8
MYS					**2,6**	3,7	**2,6**	3,7
NLD					**1,9–2,8**	2,6–3,9	**1,9–2,8**	2,6–3,9
SWE	**5,0**	6,9	**3,6**	4,9	**3,1**	4,3	**2,8**	3,9
USA					**4,4**	6,1	**2,6–3,5**	3,6–4,8

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.

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

Country	Currency	2011		
		national currency	EUR	USD
AUS	AUD	1,2–2,1	0,9–1,6	1,2–2,2
AUT	EUR	1,4–5,4	1,4–5,4	1,9–7,5
CAN	CAD	1,5	1,1	1,5
CHE	CHF	1,3–2,5	1,1–2	1,5–2,8
CHN	CNY	5–9	0,6–1	0,8–1,4
DEU	EUR	0,6–1,1	0,6–1,1	0,8–1,5
DNK	DKK	8–12	1,1–1,6	1,5–2,2
FRA	EUR	0,8	0,8	1,1
ISR	NIS	4,0 – 5,0	0,8 – 1	1,1 – 1,4
ITA	EUR	0,7–1,0	0,7–1,0	1–1,4
JPN	JPY	335	3	4,2
KOR	KRW	1 200–1 400	0,8–0,9	1,1–1,3
MYS			1,3	1,8
NLD	EUR	1,1–4,7	1,1–4,7	1,5–6,5
SWE	SEK	12–19	1,3–2,1	1,9–2,9
USA	USD	1,3–1,7	0,9–1,2	1,3–1,7

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

Figure 9 – Evolution of price of PV modules in selected reporting countries accounting for inflation effects – Years 2001–2011 (Normalized to 2011)

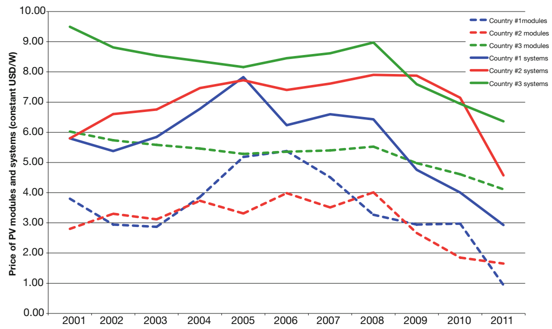

Figure 10 – Evolution of price of PV modules and small-scale systems in selected reporting countries accounting for inflation effects – Years 2001–2011 (2011 USD)

along the PV industry supply chain. Export activities continue to play an important role and a number of countries have consolidated their international positions at points along the supply chain. In 2011 the highlights include manufacturing equipment from Switzerland, silicon feedstock from China, Korea, the US and Germany, PV cells from China, Japan, Korea and the US and PV modules from China, Japan and Korea.

The total value of business in 2011 amongst the IEA PVPS countries (now including China) is approximately 110 BUSD, having grown by more than an order of magnitude over the previous five years.

In parallel with the business value of PV production and markets, the economic value in the 14 IEA PVPS countries presented in Table 8 can be characterized by the total direct employment of around 900 000 persons across research, manufacturing, development and installation. The large increase compared to last year's figure is due to the inclusion of the massive Chinese PV sector. Comparing directly with the countries reported in 2010, the number of labour places has remained at roughly the same level in 2011, an encouraging outcome given the prevailing global economic situation. The strong market growth in an increasing number of countries (see Table 3b for example) means that the risks to business of relying on single markets have diminished. At the same time, new business risks are clearly emerging with the growth of global manufacturing competition. This can provide a challenge for politicians seeking to boost domestic employment numbers in the renewable energy sector by encouraging strong demand for PV – often met significantly by imports.

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

Country	Research, development, manufacturing and deployment labour places
AUS	10 600
AUT	4 181
CAN	5 320
CHE	10 000
CHN	500 000
DEU	128 000
FRA	27 400
ITA	55 000
JPN	45 000
KOR	11 300
MYS	9 076
NLD	622
SWE	456
USA	100 237

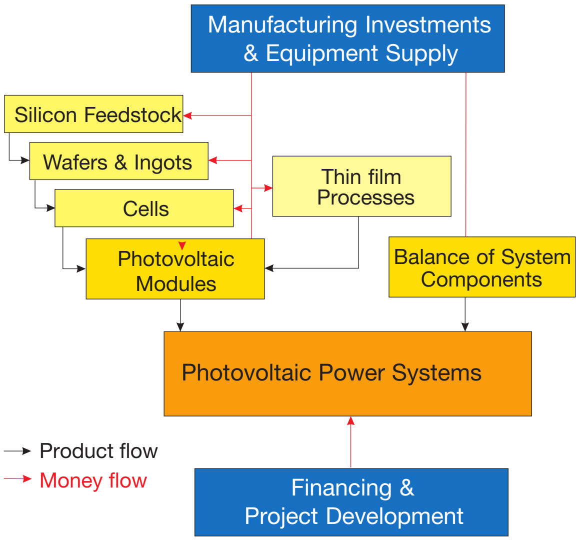

Figure 11 – Photovoltaic (PV) industry supply chain

Ginza Mitsukoshi department store, Ginza, Chuo-ku, Tokyo, Japan

3. *Policy, regulatory and business 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. This section outlines some of the initiatives promoting growth of PV markets, and also related indirect policy and business issues. More detailed discussion can be found in the national survey reports of each country.

PV public support measures (particularly feed-in tariffs) have recently significantly boosted the quantity of PV installed in many markets as discussed earlier in this report, and have increased community, building sector personnel and electricity utility awareness dramatically. Today, PV deployment is occurring within an environment of growing concerns in the community about rapidly escalating electricity bills, PV prices falling more rapidly than anticipated and pressures on governments worldwide to better manage their public subsidy programmes in challenging economic times.

In general, any support measures 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?

An outline of the range of PV support mechanisms in place in the IEA PVPS countries during 2011 can be found in Table 9. A brief description of these measures can be found in section 1.3 of this report and further details are available in the relevant national survey reports, available from the IEA PVPS website. A brief outline of the measures is given in the following box.

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 initially higher than the retail electricity rates being paid by the customer, but now sometimes similar or lower
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

Nearly all countries now offer or are about to implement **feed-in tariffs** of some description for PV electricity. The journey can be quite exciting. In Malaysia, within three hours of the 2011 launch of the national FiT the allocated quota for the commercial sector projects was completely filled.

FiT approaches have successfully driven grid-connected PV investments in large-scale (multi-MW) plants, smaller-scale building-integrated applications and combinations of both. The FiT can be national-scale, state-based or even operate at the local community or utility level. Sweden has a good example of a local feed-in tariff programme. The local electricity utility company in the Sala-Heby municipal area has agreed to buy PV electricity from a small PV power community at a price higher than the normal market price. Initial profits for the community will be spent on increasing the scheme's production capacity but after five years part of the profit will be distributed to members according to shareholdings.

Feed-in tariffs have been clearly seen as the prime mechanism for promoting strong growth in grid-connected PV applications, although they are by no means the only method of PV promotion that can deliver positive results (for example, the US with tax credits and RPS operating successfully across market segments and Japan's positive experience with its capital subsidies for the residential PV market).

FiTs have also been associated with explosive markets, profiteering, political interference, over-reliance on imports, market collapses, business closures and so on. The various design features of feed-in tariff schemes are now well known – 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.

In today's environment a well-functioning FiT scheme usually implies the ability to adjust incrementally for changes in PV system prices and other factors. In Germany, with parity already being reported with retail electricity prices, the feed-in tariff depends on the system size and type (ground-mounted or attached to a building) and is adjusted in response to real market conditions. There is also a growing emphasis on features that encourage the self-consumption of the PV electricity. Confidence in the process is further enhanced by the fact that all rates are guaranteed for an operational period of 20 years. In France, the decrease of the feed-in tariffs every three months depends on the number of grid-connection requests made during the previous quarter. Switzerland's 18 % drop in the FiT price allows the cap on installations to be lifted, creating a larger market. Austria simply removed systems of less than 5 kW capacity from the scheme. There are many permutations and combinations of policy responses.

More often than not, in response to an explosive market, the political course of action is quite reactionary. In Australia, feed-in tariffs are organized at the state level (by different governments) and 2011 saw the end or significant scaling back of this type of support in almost all jurisdictions. In NSW the gross feed-in tariff of 0,6 AUD/kWh (that lasted for less than one year) had been dropped to 0,2 AUD/kWh (less than the retail price of electricity) and was closed to new applications in April 2011. The Victorian feed-in tariff closed from 30 September 2011 when it had reached its cap. The South Australian FiT was reduced from 0,44 AUD/kWh to 0,16 AUD/kWh from 1 October 2011 and eligible systems receive the payment only until 30 September 2013. In the ACT the 15 MW cap was reached by 13 July 2011 and the scheme was closed. The Western Australian FiT closed to new applications from 1 Aug 2011. The salutary lesson is that while the FiT approach does appear neat and simple on the surface, it does take a lot of effort to firstly get it correct, and secondly to keep it functioning as desired in dynamic PV and electricity markets. Probably one of the key lessons is just how much effort is involved to develop reasonable boundary conditions and operational parameters.

But, the Australian PV market remains healthy. This is also being seen elsewhere. In the Netherlands, for example, a host of new initiatives for the implementation of PV that are independent of governmental subsidies have been set up. The Wij Willen Zon (We want sun) foundation buys in-bulk to reduce the individual prices of modules, and there are many similar initiatives operating in the Netherlands. Additionally, lease-back arrangements and cooperative organizational structures are allowing consumers to become (partial) owners of PV systems and/or use solar electricity without making large investments. In fact, in many countries, the debate is now shifting from if or how to implement a feed-in tariff to how to move to the self-sustaining market post feed-in tariff.

Table 10 provides a broad overview of some of the key PV support measures. PV technology can now be regarded as mainstream in many of the countries with expanding PV markets, and the main policy challenge is to decide how best to move towards true market transformation. Within the coming years the sustainable market will eventuate as parity with retail electricity prices occurs in different markets and market segments. Bottom-up initiatives represent a clear new trend in countries such as the Netherlands. For governments the issue now is how to best manage the transition period leading to sustainable markets for PV. 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.

The **regulatory approach** commonly referred to as the ‘renewable portfolio standard’ (RPS) is a powerful policy tool to increase renewable energy deployment particularly in more competitive electricity markets. Rather than simply encouraging the lowest direct cost renewable energy options for consideration, RPS can be further developed to provide direct support for PV deployment. The most obvious example is the US where a number of PV-specific state-based regulatory approaches, such as PV set-asides, have been implemented. Other countries allow PV electricity to earn multiple certificates compared to other renewable technologies, with the multiplier able to be varied over time to reflect the increasing cost-competitiveness of PV electricity. Most interestingly,

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

	AUS	AUT	CAN	CHE	DNK	DEU	FRA	ISR	ITA	JPN	KOR	MYS	NLD	SWE	USA
Enhanced feed-in tariffs[1.] USD cents/kWh	45	53	81	66,5 [6.]		40 [5.]	56,5	+	53	52,5	48	+	+	57[2.]	+
Direct capital subsidies	+	+		+		+	+			+	+		+	+	+
Green electricity schemes	+	+		+		+			+	+					+
PV-specific green electricity schemes		+		+									+		+
Renewable portfolio standards (RPS)	+									+	+[3.]			+	+
PV special treatment, in RPS	+									+	+				+
Investment funds/ finance schemes for PV			+			+							+		+
Tax credits			+	+			+			+		+	+		+
Net metering/ net billing	+	+	+	+	+	+			+			+	+	+	+
Commercial bank activities	+					+		+		+			+		+
Electricity utility activities	+		+	+	+	+				+	+		+	+	+
Sustainable building requirements	+		+	+	+	+					+		+		
Indicative household retail electricity price [4.] USD cents/kWh	13,5–24	25	7	18	39	35	18	12,5	24,5	22,5–30	20	13,4	30,5	23	11,8

Notes:
1. *Highest feed-in tariff offered in 2011 in USD cents/kWh*
2. *Local, community-based scheme*
3. *Demonstration programme*
4. *Typical residential kWh price expressed in USD cents (1 USD/100), including all taxes but not including variations due to time of use, total electricity consumption or any fixed rates*
5. *During 2011 FiTs for plants <30 kW have been amended from 40 cents/kWh to 34 cents/kWh on 1 July*
6. *Swiss FiTs range from 34,3 cents/kWh for large ground-mounted systems up to 66,5 cents/kWh for small building-integrated systems.*

to manage the transition to grid parity, the Korean Government is replacing their feed-in tariff scheme from 2012 with RPS, sending a strong message to electricity utilities about their role in the PV market of the future.

The building sector also has a large role to play and sustainable building regulations are an emerging force in a large number of countries. These include requirements on new building developments (residential and commercial) and also in some cases on properties for sale. PV may be included in a suite of options for reducing the building's energy footprint or specifically mandated as an inclusion in the building development. This approach will significantly grow the commercial sector building PV market that has hitherto been under-represented in many national markets. Still in Korea, the Public Building Obligation Programme sees new public buildings larger than 3000 square meters spending 5 % of their total construction budget installing renewable energy facilities, leading to 14,6 MW of PV installed during 2011. In Denmark the EU directive on energy consumption in buildings, minted into a revised

Table 10 – Characteristics of some key support measures

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

national building code, allocates PV electricity a factor of 2,5 in the calculation of the energy footprint of a building. A tangible impact on PV deployment can now be seen and tightening of the building codes is likely.

Municipalities and regions in Denmark have demonstrated a rapidly growing interest in PV technology. The main drivers here are the climate change action plans and targets formulated by most municipalities. Municipalities then follow-up with demonstration of the PV technology by installing PV on the many municipal buildings such as schools, hospitals, kindergartens, homes for the elderly and so on. Many municipalities combine the PV demonstration systems with information campaigns targeting both the citizens using the municipal buildings and the community in general.
Similarly, many local governments around Australia have active greenhouse gas reduction and renewable energy support programmes and the deployment of PV in a municipal context is expected to increase considerably in the coming years. As an example, the Fraser Coast Regional Council has established a Community Solar Farm that will generate approximately 630 MWh annually - enough to power approximately 100 homes and save around 600 tonnes of carbon emissions every year.
Public concerns about nuclear power generation saw an upsurge in activity in Japan with 875 local governments and municipalities implementing their own subsidy schemes to promote the deployment of residential PV systems. Recipients can take advantage of these subsidies in addition to the national subsidies provided by METI. Halfway around the world, the same concerns have also seen an increase in interest amongst local governments and municipalities in Switzerland with PV increasingly installed on public buildings.

In the Netherlands, the province of Noord-Brabant stimulated the development of solar energy with a substantial investment, aimed at positioning this region at the top of solar energy technology and innovation in Europe. Investment is used to attract additional research and knowledge development. The knowledge developed in institutions, laboratories and test facilities is made available to local companies, allowing them to apply new capabilities commercially, with the goal of increasing the solar-related employment opportunities in the region.

Of course, local authorities can also exert a positive impact on the market through their role as the permitting body. In the US, Vermont has implemented a pre-defined permitting process for PV installations of 10 kW and under, to decrease paperwork processing times and regulatory uncertainty. At the municipal level, the City of Los Angeles has moved towards decreasing permitting barriers by eliminating building height restrictions for roof mounted PV systems, as long as the system under consideration adheres to set-back requirements. The City of Santa Cruz has demonstrated genuine leadership in promoting residential solar by eliminating building permits altogether for PV systems that meet certain criteria.

Worldwide, **electricity utilities** are now investing in very large-scale PV plants or asking how they can benefit from meeting their customers' interest in PV plants or PV electricity, often driven by government mandates and increasingly leading to the pursuit of business opportunities. These issues provide benefits, opportunities and challenges for electricity utilities and their industry regulators. Already, on the technical side, concerns have been raised about high penetration of PV in some electricity networks.
It is highly likely that the electricity utilities will have a more significant role to play in PV deployment in coming years, particularly the 'new' electricity network businesses (operating smart grids, with advanced metering and communications, encouraging customers to be more than just a load, electric vehicles becoming significant, storage playing an increasing role in system operations and so on).
On the business side, what will be the approach to widespread deployment of PV taken by these utilities and their industry regulators, who is going to pay for some of the network-related issues and how might PV be financed into the future? These are key issues for the coming years. An outline of current electricity utility PV activities can be found in the national reports and some examples of these follow.

In the past, Australian electricity utilities, as elsewhere, were heavily involved in PV demonstration programmes through their own R&D arms. More recently (in the competitive and disaggregated electricity market) electricity utility interest has largely been driven by government programmes, such as the Solar Cities and Smart Grids programmes. Further, all electricity retailers must obtain renewable MWhs under the Renewable Energy Target and some have installed their own PV systems to contribute to meeting their liability.

Solar powered ski-lift in Tenna, Switzerland, courtesy Solarskilift.ch

Some utilities have also established solar businesses and sell PV systems to their customers. The Electricity Networks Association has begun to examine issues of high PV penetration and is preparing guidelines and protocols for utilities. In Alberta, Canada, Calgary's ENMAX electricity utility offers installed PV systems with no upfront investment cost and a 15-year lease-to-own programme, including parts and labour warranties and ongoing service agreements.

The Danish transmission system operator, Energinet.dk, has for several years expressed interest in PV, both as a potential contributor to electricity supply and as support for the electricity grid. The distribution utilities have also promoted the use of PV and since 2009 several distribution utilities have included PV technology in their portfolio of products. EnergiMidt used to provide a capital incentive to customers inside its service area but is now marketing PV technology without any special support. Most distribution utilities simply regard PV as a relevant standard product and some offer finance packets and payment via the electricity bill. Through its national federation, Dansk Energi, the Danish utilities have announced that they will not charge PV system owners for the use of the grid and, in addition, several distribution utilities do not charge for the metering system needed to benefit from the net-metering scheme. However, these free-of-charge services could be expected to change to a fee-for-service scheme when PV penetration levels increase significantly.

In Germany, where the regulations of the EEG are so successful in eliminating barriers to private sector investment and the electricity utilities have played a subordinate role, the first initiatives by the electricity utilities are now being seen in the PV market.

In Japan, electricity utilities constructed MW-scale PV power plants ahead of schedule during 2011. Several utilities now operate large-scale PV power plants. Electricity utilities have started installing PV systems on the rooftops of properties owned by their customers and have also started installing PV at their own facilities.

Korean electricity generation companies signed the Renewable Portfolio Agreement with the government in order to increase the share of renewable energy in electricity generation. As a precursor to the Renewable Portfolio Standard replacing the feed-in tariff scheme from 2012, a RPS Demonstration Programme has been run. Electricity companies have constructed their own PV plants or have purchased PV electricity from private operators under this programme.

In the Netherlands electricity utilities sometimes offer turnkey PV systems in package deals with an energy contract. Some utilities offer additional net metering beyond the mandatory limit of 5 000 kWh annually. In combination with a long-term energy contract with the company, Greenchoice has offered 5 000 of its customers PV systems under a leasing arrangement, to generate their own electricity for a fixed electricity price.

The interest in PV from the electricity utility businesses in Sweden has increased. From one company buying surplus electricity previously, 2011 saw a number of electricity utilities launching compensation schemes and some network businesses introduced net metering. In Switzerland, local and regional utilities especially have begun to design new 100 % renewable energy products incorporating an increasing share of PV. In addition they have implemented changes to procurement strategies in order to significantly increase the availability of renewable electricity.

Electricity utility interest continues to increase in the United States, with the key drivers being the 30 % federal tax credit at the national level and Renewable Portfolio Standards at the state level. Four broad categories of utility PV business models can be seen in the US: utility ownership of assets, utility financing of assets, development of customer programmes and utility purchase of solar output. Ownership of assets allows the utility to take advantage of the tax credit benefits, earn a rate of return on the asset (investor-owned utilities) and provides control over planning, siting, operation and maintenance. Financing of Solar Assets is a PV business option for utilities that choose not to own solar assets for tax, cost, regulatory, or competitive considerations. Customer Programmes are designed to increase access to PV electricity by lowering costs, for all parties, compared to a traditional customer-sited PV system. These may involve a community or centralized PV system and specific classes of participating customers to whom a proportional share of the output can be allocated offsetting their electricity bill directly, or by offering a fixed-rate tariff that is attractive compared with current (and future) retail electricity prices. Utility Purchase of Solar Output is a business model often applied by publically owned utilities to create value for their communities by supporting local PV development (for example by offering a feed-in tariff to purchase PV electricity).

The up-front capital requirements of PV installations remain a common barrier to deployment. Third-party **financing schemes** (including leases and power purchase agreements) that address high up-front capital requirements are becoming more common. In 2011 approximately 47 % of residential PV systems installed through the California Solar Initiative used third-party financing arrangements. A number of

Farmhouse in rural Switzerland, Photo: BE Netz AG

Australian PV installation companies offer finance or leasing options, especially for commercial systems. For many business customers, leasing makes better economic sense, since the interest payments on a lease option would be tax deductible whereas the capital cost option only provides depreciation over 20 years.

In the Netherlands several banks provide Green Mortgages (ASN, Triodos, ING, Rabobank, Fortis), offering 1 % to 2 % discounts on market interest rates. PV in Germany receives support from local fiscal authorities (in the form of tax credits) and the state owned bank KfW-Bankengruppe provides loans for application of renewable energy and measures to reduce energy consumption. Canadian non-profit organizations such as the Ontario Sustainable Energy Association and the Community Energy Partnership Programme are facilitating community co-operative investments in PV with toolkits, workshops and user-group forums, and grant money for the initial investment.

In all these discussions about policy and business in the wealthy countries of the world it should not be forgotten that PV technology 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 and in particular the one third of the world's population that still does not (and will not) have access to grid electricity

Standards and codes

Established in 1981, the Technical Committee (TC) 82 of the International Electrotechnical Commission (IEC, www.iec.ch) promotes PV standardization through the preparation of international standards both for PV systems and for all the elements in the entire PV energy system. Currently 33 countries are active participants in TC 82 and a further 15 have observer status. Increased involvement has been reported from Asian countries. For example, Korea adopts the IEC TC 82 standards as Korean Standards under the responsibility of the Korea Agency for Technology and Standards. 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. It is organized in two working groups – WG1, concerned with wafers, cells and modules, and WG2, concerned with BOS components and systems. In 2011, CLC/TC 82 issued seven new European publications.

During 2011 TC 82 published the following:

- IEC 60904-5 Ed. 2.0 – Photovoltaic devices – Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method
- IEC 61701 Ed. 2.0 - Salt mist corrosion testing of photovoltaic (PV) modules
- IEC 61730-1 am1 Ed. 1.0 – Amendment 1 – Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction
- IEC 61730-2 am1 Ed. 1.0 – Amendment 1 – Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing
- IEC 61853-1 Ed. 1.0 – Photovoltaic (PV) module performance testing and energy rating – Part 1: Irradiance and temperature performance measurements and power rating
- IEC 62109-2 Ed. 1.0 – Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters
- IEC 62253 Ed. 1.0 – Photovoltaic pumping systems – Design qualification and performance measurements

Canada previously adopted the IEC standards that define the test and qualification requirements for PV modules and in 2011 adopted IEC 61730 for PV module safety. Canada has also provided support for the development of an international standard for electricity network communication and distributed energy resources, reflected in the IEC 61850-7-420 Ed.1 standard for basic communication structure, including PV device and system logical nodes.
A pressing topic in the development of product standards in the United States is the need for a fire-safety test for PV systems, rather than for modules alone. In addition, building codes can play an important role for PV installations and there are many PV-related changes being considered, both for residential and commercial systems. The Solar Energy Industries Association, the Solar America Board of Codes and Standards and the industry in general are involved in the development process.

In Australia, the main areas still being addressed relate to system safety, with major efforts being put into revision of the Australian PV array installation standard and the grid connection standard.

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 broadly consistent with the corresponding IEC documents; however some of them reflect the unique circumstances of Japan. As a complement to the current standards JET conducts a certification programme for the performance and reliability of PV system components. JET started a new certification program for inverters for multiple grid-interconnection of PV systems in 2011, and has certified a technology to prevent islanding operation in the case of multiple inverters.

China's national Standard Administration Commission has established a team to promote the PV industry and its standards, and the China Electricity Council (CEC) has the responsibility for grid-connected PV standardization. Sweden's SolEl programme has compiled and released a summary of all important standards and guidelines for PV system installation and maintenance.

4. Summary of trends

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

- Almost 28 GW of PV capacity were installed in the IEA PVPS countries during 2011 – about double the amount as in the previous year. This brought the cumulative installed capacity to 63,6 GW. By far the greatest proportion (60 %) was installed in Italy and Germany alone. If China, the US, Japan and France are also included, then over 86 % of PV installations in 2011 occurred in six countries. Continued dramatic growth of annual grid-connected PV installations was evident, with significant growth of the annual market in a number of the largest markets. Nine (almost 11) countries rank in the GW cumulative installed PV capacity grouping (up from five the previous year). Nine countries have, or are close to achieving, annual markets exceeding 1 GW. The market leader in 2011, Italy, saw its cumulative installed capacity grow by a factor of more than three and a half; China's cumulative installed capacity increased more than four-fold; Germany's cumulative installed capacity grew at 43 % whereas Japan's growth rate approached 36 %. Cumulative

Table 11 – Cumulative installed PV power and annual percentage increase

Year	Off-grid		Grid-connected		Total	
	Cumulative (MW)	Increase (%)	Cumulative (MW)	Increase (%)	Cumulative (MW)	Increase (%)
1992	78		27		103	
1993	94	21	33	22	127	23
1994	112	19	39	18	151	19
1995	132	18	49	26	181	20
1996	158	19	61	24	219	21
1997	187	19	94	54	281	28
1998	216	15	139	48	355	26
1999	244	13	227	63	471	33
2000	277	14	401	77	678	44
2001	319	15	647	61	966	42
2002	354	11	983	52	1 337	38
2003	410	16	1 408	43	1 818	36
2004	450	10	2 426	72	2 876	58
2005	485	8	3 758	55	4 243	48
2006	535	10	5 347	42	5 882	39
2007	663	24	7 684	44	8 347	42
2008	741	12	13 752	79	14 493	74
2009	883	19	19 875	45	20 758	43
2010	980	11	33 973	71	34 953	68
2011	1 190	21	62 421	84	63 611	82

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

installed capacity in the US increased at close to 57 %. France's cumulative installed capacity increased by a factor of 2,4.

- The dominance of the grid-connected markets extended even further, now accounting for over 98 % of the cumulative installed PV capacity. Off-grid markets largely tend to be ignored. This is unfortunate as these applications have the scope to dramatically change the lives of some of the world's most disadvantaged peoples. The off-grid market itself is healthy with sustained, solid growth over decades, largely unsupported by public funding.

- After significant increases in R&D expenditure in 2010 compared to 2009, the situation remained relatively flat into 2011. The main exceptions were Japan, Korea and the US that all experienced modest funding increases. It is clear that governments still clearly identify the benefits of further development of PV and associated technologies, better integration with existing energy systems and new innovations. The clear leader in total R&D funds is the US; other reporting countries with significant R&D spending are Japan, Korea and Germany.

- In 2011 solar photovoltaic grade silicon feedstock supply was dominated by China, the US, Korea, Germany and Japan, with smaller levels of production in Canada and Norway. Of the main movers in 2011, China increased production by 87 %, and also increased imports by 36 % from the previous year. Korea increased polysilicon production capacity by 60 %.

- China, Germany, Korea, Malaysia, Japan and the US are the dominant producers in the ingot and wafer section of the PV industry value chain with additional manufacturing capacity in Italy, Switzerland, France and the USA. Crystalline silicon wafer prices dropped by over 40 % during 2011 causing some companies to re-evaluate their business models. One of these was REC Corporation of Norway that announced the closure of its Norwegian wafer manufacturing facilities and shifting of production to Singapore. New market players and increased production have been reported from non-PVPS countries, particularly Taiwan.

- Total PV cell production for 2011 in the IEA PVPS countries is estimated to be 29,9 GW, a 70 % increase from the previous year and around 80 % of global PV cell production. China was the lead producer of PV cells in 2011, manufacturing around 20 GW of cells, double the amount manufactured in China in 2010. Other PVPS countries manufacturing at the GW scale in 2011 include Germany with 2,5 GW, Japan with 2,7 GW, Malaysia with an estimated 2 GW, South Korea with 1 GW and the US with 1,1 GW. Taiwan produced 4,3 GW of PV cells; other major non-PVPS countries manufacturing PV cells are the Philippines, Singapore and India.

- PV module production in PVPS countries accounted for more than 90 % of the modules produced globally in 2011. The picture for PV module production is similar to that for cell production with 34 GW of wafer based and thin-film modules produced in the IEA PVPS countries. Again, the largest producers were China producing 21 GW (approaching 60 % of the global production), Germany 2,3 GW, Japan 2,5 GW, Malaysia an estimated 2 GW, Korea 1,7 GW and the US 1,3 GW. In total the PVPS countries produced approximately 30 GW of wafer based modules and 3,9 GW of thin-film modules.

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

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

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Power installed during year in IEA PVPS reporting countries (MW)	371	481	1 058	1 367	1 639	2 465	6 146	6 265	14 192	27 970
Module production during year in IEA PVPS reporting countries (MW)	482	667	1 160	1 532	1 668	2 690	4 000	6 500	20 000	34 000 *(estimate)*

- Thin-film PV manufacturers are facing heightened cost competition with crystalline silicon PV products. A number of companies with smaller production capacities, and new entrants trying to raise their production capacities, have reviewed their plans and restructured their businesses. In 2011, activities concerning concentrating PV (CPV) cell/modules were reported by several member countries.

- In 2011, drastic changes were observed in the global business environment for the PV industry. The global PV market largely shifted from a seller's market to a buyer's market due to the magnitude of capital investment in production. PV prices declined largely because of the gap in supply and demand, rather than the traditional effects of mass production and R&D activities. 2011 saw an increase in the number of GW-scale manufacturers, a widening of the supply/demand gap, a maturing of the supply chain and the emergence of trade tensions.

- On average, the cost of the PV modules in 2011 accounted for approximately 50 % of the lowest achievable prices that have been reported for grid-connected systems. In 2011 the average price of modules in the reporting countries was about 1,4 USD/W, a decrease of almost 50 % compared to the corresponding figure for 2010, following a decrease of 20 % the previous year.

- The lowest achievable installed price of grid-connected systems in 2011 varied between countries, with the average price of these systems being about 3,6 USD/W, about 17 % lower than the average 2010 price. Prices as low as around 2 USD/W were reported; typically prices were in the range 2,6 USD/W to 4,4 USD/W.

- The total value of business in 2011 amongst the IEA PVPS countries (now including China) was approximately 110 BUSD, having grown by more than an order of magnitude over the previous five years. Total direct employment is reported to be around 900 000 persons across research, manufacturing, development and installation. The large increase compared to previous year's figure is due to the inclusion of the massive Chinese PV sector. Comparing directly with the countries reported in 2010, the number of labour places has remained at roughly the same levels in 2011.

- Nearly all the PVPS countries now offer or are about to implement feed-in tariffs (FiT) of some description for PV electricity. FiT approaches have successfully driven grid-connected PV investments in large-scale plants, smaller-scale building-integrated applications, and combinations of both, can be national-scale, state-based or even operate at the local community or utility level. FiTs have been clearly seen as the prime mechanism for promoting strong growth in grid-connected PV applications, although they are by no means the only method of PV promotion that can deliver positive results. FiTs have also been associated with explosive markets, profiteering, political interference, over-reliance on imports, market collapses, business closures and so on. In today's environment a well-functioning FiT scheme usually implies the ability to adjust incrementally for changes in PV system prices and other factors.

- Within the coming years the sustainable market will eventuate as parity with retail electricity prices occurs in different national markets and market segments. Support policies will begin to shift from handouts of public money to focus more on enabling strategies, appropriate regulation and development of innovative business models.

- The regulatory approach known as the 'renewable portfolio standard' (RPS) is a powerful policy tool to increase renewable energy deployment, particularly in more competitive electricity markets. Sustainable building regulations are an emerging force in a large number of countries and will significantly grow the commercial sector building PV market that has hitherto been under-represented in many national markets. Municipalities, regional and local jurisdictions have demonstrated a rapidly growing interest in PV technology. Worldwide, electricity utilities are now investing in very large-scale PV plants or asking how they can benefit from meeting their customers' interest in PV plants or PV electricity, often driven by government mandates and increasingly leading to the pursuit of business opportunities. While the up-front capital requirements of PV installations remain a common barrier to deployment, third-party financing schemes (including leases and power purchase agreements) that address high up-front capital requirements are becoming more common.

Table 13 – National survey report/national information authors

Australia	AUS	Muriel Watt & Robert Passey, IT Power Australia, Warwick Johnston, SunWiz Consulting, for the Australian PV Association
Austria	AUT	H. Fechner, N. Prüggler & P. Eder-Neuhauser, University of Applied Science Technikum Wien
Belgium	BEL	Gregory Neubourg, Chargé de projets, Point info Energies Renouvelables à Bruxelles
Canada	CAN	Josef Ayoub, Lisa Dignard-Bailey & Yves Poissant, CanmetENERGY, Innovation and Energy Technology Sector, Natural Resources Canada
China	CHN	Xu Honghua, Charlie Dou, Wang Sicheng, Lv Fang
Denmark	DNK	Peter Ahm, PA Energy A/S
France	FRA	Yvonnick Durand, ADEME
Germany	DEU	Lothar Wissing, Forschungszentrum Jülich, Projektträger Jülich on behalf of BMU
Israel	ISR	Yona Siderer and Roxana Goldman-Dann, Ben-Gurion University of the Negev
Italy	ITA	Salvatore Castello, Anna De Lillo, ENEA; Salvatore Guastella, Fabrizio Paletta, RSE SpA
Japan	JPN	Hiroyuki Yamada, NEDO; Osamu Ikki, RTS Corporation
Korea	KOR	Kyung-Hoon Yoon, KIER
Malaysia	MYS	Dato' Hj. Badaruddin bin Mahyudin, Ministry of Energy, Green Technology & Water; Pn Badriyah Abdul Malek , Sustainable Energy Development Authority Malaysia
Mexico	MEX	Jaime Agredano Diaz & Jorge M Huacuz Villamar, Instituto de Investigaciones Electricas
Netherlands	NLD	Ecofys Netherlands BV, for NL Agency and the Ministry of Economy, Agriculture and Innovation
Norway	NOR	Lars Bugge and Fritjof Salvesen, Asplan Viak – KanEnergi AS, for the Research Council of Norway
Portugal	PRT	Pedro Paes, EDP
Spain	ESP	Vicente Salas, Electronic Technology Department, Universidad Carlos III de Madrid
Sweden	SWE	Johan Lindahl, Ångström Solar Center, Uppsala University, for the Swedish Energy Agency
Switzerland	CHE	Pius Hüsser, Nova Energie GmbH
Turkey	TUR	Mete Çubukçu & Metin Çolak, Turkish PV Technology Platform (UFTP)
United Kingdom	GBR	Paul Rochester, Department of Energy and Climate Change
United States of America	USA	Kristen Ardani & David Feldman, NREL (with input from SEIA and GTM Research)

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 RTS Corporation (particularly Akiko Murata and Izumi Kaizuka), Peter Ahm and Greg Watt.

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Table 14 – currency exchange rates (average for calendar year 2011)

Country	Currency and code	Exchange rate (1 USD =)	Country	Currency and code	Exchange rate (1 USD =)
Australia	dollar (AUD)	0,97	Japan	yen (JPY)	79,84
Canada	dollar (CAD)	0,99	Korea	won (KEW)	1 107,81
China	yuan (CNY)	6,46	Sweden	krona (SEK)	6,48
Denmark	krone (DKK)	5,36	Switzerland	franc (CHF)	0,89
Israel	NIS	3,58	United States	dollar (USD)	1
			Austria, France, Germany, Italy, the Netherlands	euro (EUR)	0,72
(source: OECD Main Economic Indicators 2012)					

Exchange rates

Table 14 lists the reporting countries, corresponding currency codes, and the exchange rates used to convert national currencies. Exchange rates represent the 2011 annual average of daily rates (source: OECD Main Economic Indicators July 2012).

PV on a Brewery in Switzerland, Photo: ADEV Liestal

Photovoltaic (PV) technology note

The key components of a photovoltaic power system are various types of ***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 and multicrystalline silicon, compound semiconductor) or thin film. Currently crystalline silicon technologies account for about 80 % of the overall cell production in the PVPS countries.
Single crystal silicon (sc-Si) PV cells are formed with the wafers manufactured using a single crystal growth method and have commercial efficiencies between 15 % and 20 %. Multicrystalline silicon (mc-Si) cells, usually formed with the multicrystalline wafers manufactured from a bidirectional solidification process, are becoming increasingly popular as they are less expensive to produce but are marginally less efficient, with average conversion efficiency around 14 %. Quasi-monocrystalline silicon PV cells, manufactured using same process as multicrystalline silicon PV cells, are gaining attention more recently. III-V compound semiconductor PV cells are formed by growing materials, which generate electricity, such as GaAs on the Ge substrates and have high conversion efficiencies of 35 % and more. Due to the high cost, they are applied for concentrating PV systems with tracking systems.
Thin film cells are formed 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 less expensive 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). Organic thin-film PV cells, using dye or organic semiconductors, have created interest and research and development activities are underway.
Further research and development is being carried out to improve the efficiency of all the basic types of cells with laboratory efficiency levels for single crystal cells of 25 %, and for thin film technologies of 20 % 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 encapsulate PV cells formed into a single substrate, in 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 utilization 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 fixed 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.

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