IEA INTERNATIONAL ENERGY AGENCY

TRENDS IN PHOTOVOLTAIC APPLICATIONS

Survey report of selected IEA countries between 1992 and 2006

PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

Report IEA-PVPS T1-16:2007

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Contents

Foreword

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Co-operation and Development (OECD). The IEA carries out a comprehensive programme of energy co-operation among its 26 member countries and with the participation of the European Commission.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the collaborative research and development agreements within the IEA and was established in 1993. The mission of the programme is to "enhance the international collaboration efforts which accelerate the development and deployment of photovoltaic solar energy as a significant and sustainable renewable energy option".

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

The IEA PVPS Programme is pleased to present the twelfth edition of the international survey report on Trends in Photovoltaic Applications. Once again, there has been a substantial market growth in 2006, with an ongoing trend in grid-connected applications. The total installed capacity in IEA PVPS member countries has reached 5,7 GW by the end of 2006. While a large fraction of the recent market development is taking place in only a few countries, there are clear signs that the number of countries with substantial markets is increasing, thus providing for a more balanced global market development. Industrial production capacity is rapidly expanding with important developments in countries that are not members of IEA PVPS. Although the price reduction of PV has slowed down or even reversed over the past couple of years due to the silicon shortage, latest figures and trends indicate that the cost reduction of PV is likely to speed up in the coming years. These encouraging developments are complemented by energy issues regaining a high priority on the political agenda. The developments on the policy level are seeing concrete outcomes in terms of new initiatives related to PV, the Solar America Initiative being just one example of such new initiatives. Keeping track of all the developments in and around the PV sector on the global level is a challenge which IEA PVPS is taking forward and we are pleased to provide a global network of analysis and information. I trust that this new edition of Trends in Photovoltaic Applications will find many interested readers and I would like to thank all experts who have contributed to this report.

Stefan Nowak
Chairman, IEA PVPS Programme

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

August 2007

Introduction

Trends report scope and objective

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

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

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

This report presents the results of the 12th international survey. It provides an overview of PV power systems applications, markets and production in the reporting countries and elsewhere at the end of 2006 and analyzes trends in the implementation of PV power systems between 1992 and 2006.

Country Heights Damansara, 4 kW, Malaysia

Survey method

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

Following technical review by the national representatives the report was approved by the IEA PVPS Executive Committee. A list of the national authors is given at the end of this publication.

Definitions, symbols and abbreviations

Standard ISO symbols and abbreviations are used throughout this report. The electrical generation capacity of PV modules is given in watts (W). This represents the rated power of a PV module under standard test conditions of 1000 $W \cdot m^{-2}$ irradiance, 25°C cell junction temperature and solar reference spectrum AM 1,5.

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

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

1 Implementation of photovoltaic systems

1.1 Applications for photovoltaics

There are four primary applications for PV power systems:

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

PV for wireless LAN, Israel

Off-grid non-domestic installations were the first commercial application for terrestrial PV systems. They provide power for a wide range of applications, such as telecommunication, water pumping, vaccine refrigeration and navigational aids. These are applications where small amounts of electricity have a high value, thus making PV commercially cost competitive with other small generating sources.

Grid-connected 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

Photo courtesy of Baja California State Government

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.

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.

PV plant Lamelas, Portugal

1.2 Total photovoltaic power installed

About 1,5 GW of PV capacity were installed during 2006 (an increase of 15 % over the previous year) which brought the total installed to 5,7 GW. As in recent years, by far the greatest proportion (82 %) was installed in Germany and Japan alone, and therefore care must be taken when interpreting the results given in this section of the report, as significant developments in other countries can be masked by the level and type of development in these two countries.

Furthermore, an upward revision of the German data for 2004 and 2005 was published in Germany and incorporated in this report. While the capacity installed in Germany in recent years is likely to remain a topic of discussion, it is considered important that this report continue to be updated to reflect the best information available. This will enable IEA PVPS to carry out a more realistic and rigorous evaluation of trends in PV markets and policies over the last decade or so.

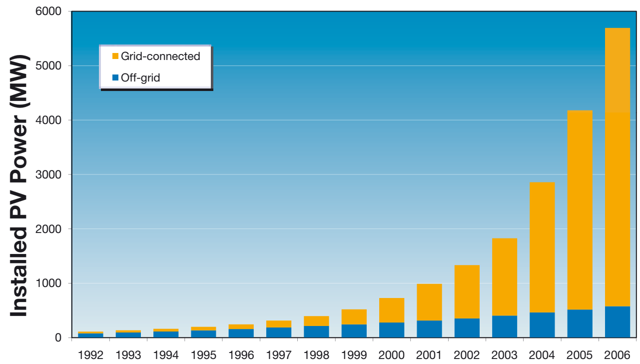

Figure 1 – Cumulative installed grid-connected and off-grid PV power in the reporting countries

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 proportion of worldwide PV capacity.

Table 1 – Installed PV power in reporting IEA PVPS countries as of the end of 2006

Country	Cumulative off-grid PV capacity (kW)		Cumulative grid-connected PV capacity (kW)		Total installed PV power (kW)	Total installed per capita (W/Capita)	PV power installed in 2006 (kW)	Grid-connected PV power installed in 2006 (kW)
	domestic	non-domestic	distributed	centralized				
AUS	23 883	36 653	9 005	760	70 301	3,5	9 721	2 145
AUT	3 169		21 263	1 153	25 585	3,1	1 564	1 290
CAN	6 680	12 296	1 443	65	20 484	0,6	3 738	384
CHE	3 050	350	23 740	2 560	29 700	4,0	2 650	2 500
DNK	80	255	2 565	0	2 900	0,5	250	210
DEU	32 000		2 831 000		2 863 000	34,9	953 000	950 000
ESP	17 800		100 400		118 200	2,7	60 500	51 400
FRA	15 015	6 539	22 379	0	43 933	0,7	10 890	9 412
GBR	324	758	12 960	0	14 042	0,2	3 165	3 007
ISR	1 084	210	11	14	1 319	0,2	275	0
ITA	5 300	7 500	30 500	6 700	50 000	0,9	12 500	12 000
JPN	1 212	87 376	1 617 011	2 900	1 708 499	13,4	286 591	285 060
KOR	983	4 960	18 323	10 467	34 733	0,7	21 209	20 929
MEX	15 019	4 573	155	0	19 747	0,2	1 054	116
NLD	5 713		43 673	3 319	52 705	3,2	1 521	1 243
NOR	7 150	390	128	0	7 668	1,7	416	53
SWE	3 630	655	555	0	4 840	0,5	603	301
USA	114 000	156 000	322 000	32 000	624 000	2,1	145 000	108 000
Estimated total	**226 751**	**347 856**	**4 773 271**	**343 778**	**5 691 656**		**1 514 647**	**1 448 050**

Notes: Portugal not included. ISO country codes are outlined in Table 12. Some countries are experiencing difficulties in estimating and/or apportioning off-grid domestic and non-domestic; in some markets the distinction between grid-connected distributed and centralized is no longer clear (eg MW scale plant in the urban environment), and mini-grids using PV are also emerging, with other problems of definition. Where definition has not been made in a national report this is shown in this table, however the totals have been estimated using the most recently available ratio from the national reports applied to the current national data. Australian off-grid domestic total includes 1 745 kW of PV on diesel grids.

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

	Cumulative installed PV power (MW)													
Country	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
AUS	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
AUT	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
CAN	1,2	1,5	1,9	2,6	3,4	4,5	5,8	7,2	8,8	10,0	11,8	13,9	16,7	20,5
CHE	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
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
DEU	8,9	12,4	17,7	27,8	41,8	53,8	69,4	113,7	194,6	278,0	431,0	1 044	1 910	2 863
ESP	4,6	5,7	6,5	6,9	7,1	8,0	9,1	12,1	15,7	20,5	27,0	37,4	57,7	118,2
FIN	1,0	1,2	1,3	1,5	2,0	2,2	2,3	2,6	2,7	3,1	3,4			
FRA	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
GBR	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	14,0
ISR	0,1	0,2	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,5	0,5	0,9	1,0	1,3
ITA	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
JPN	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
KOR	1,6	1,7	1,8	2,1	2,5	3,0	3,5	4,0	4,8	5,4	6,0	8,5	13,5	34,7
MEX	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
NLD	1,6	2,0	2,4	3,3	4,0	6,5	9,2	12,8	20,5	26,3	45,9	49,5	51,2	52,7
NOR	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
PRT	0,2	0,3	0,3	0,4	0,5	0,6	0,9	1,1	1,3	1,7	2,1	2,6	3,0	3,0
SWE	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
USA	50,3	57,8	66,8	76,5	88,2	100,1	117,3	138,8	167,8	212,2	275,2	376	479,0	624,0
Total	**136**	**164**	**199**	**244**	**314**	**396**	**520**	**729**	**989**	**1 334**	**1 828**	**2 858**	**4 180**	**5 695**

Notes: ISO country codes are outlined in Table 12. Totals reflect conservative 'best estimates' based on the latest information made available to the IEA PVPS Programme from the individual countries for previous years, and are updated as required. Finland no longer included in total. The reader is referred to the German national report for discussion about the changes to the agreed installed capacity in calendar years 2004 to 2006. Portugal did not provide 2006 survey information for this activity in a timely fashion and consequently other information sources have been used.

Table 3 – Annual market growth in selected countries

	PV power (MW) installed in calendar year											
Country	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
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
AUT	0,3	0,3	0,5	0,7	0,8	1,2	1,2	4,2	6,5	4,2	3,0	1,6
DEU	5,3	10,1	14,0	12,0	15,6	44,3	80,9	83,4	153,0	613,0	866,0	953,0
ESP	0,8	0,4	0,2	0,9	1,1	3,0	3,6	4,8	6,5	10,4	20,3	60,5
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
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
JPN	12,2	16,2	31,7	42,1	75,2	121,6	122,6	184,0	222,8	272,4	289,9	286,6
KOR	0,1	0,3	0,4	0,5	0,5	0,5	0,8	0,7	0,6	2,5	5,0	21,2
NLD	0,4	0,9	0,7	2,5	2,7	3,6	7,7	5,8	19,6	3,6	1,7	1,5
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

Notes: Countries that are experiencing (or have recorded in a past year) annual market demand of >5 MW
The reader is referred to the German national report for discussion about the agreed installed capacity in calendar years 2004 to 2006 and subsequent implications for the figures above.

The annual rate of growth of cumulative installed capacity in the IEA PVPS countries was 36 %, down a little from the highs of 2004 and 2005. Germany's cumulative installed capacity grew at 50 % (based on the revised data and down from 83 % the previous year) and Japan's growth rate was fairly steady at 20 %. The growth of the annual markets slowed in Germany and stagnated in Japan during 2006. Germany clearly has the highest level of installed capacity both in terms of total capacity (2 863 MW) and installed capacity per capita (34,9 W/capita).

With some annual markets stagnating, others started to take-off during 2006 as support programmes began to take effect, notably in Spain, Korea, Italy, the USA and France. At the same time, the decline of domestic markets continued to be observed in Austria and the Netherlands (Table 3).

Of the total capacity installed in the IEA PVPS countries during 2006 about 4 % (63 MW) were installed in off-grid projects. Figure 3 illustrates the

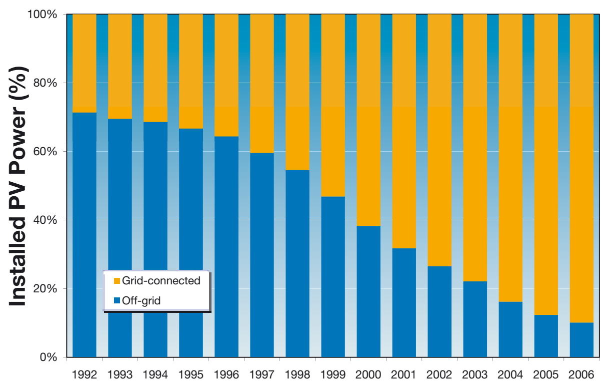

Figure 2 – Percentages of grid-connected and off-grid PV power in the reporting countries

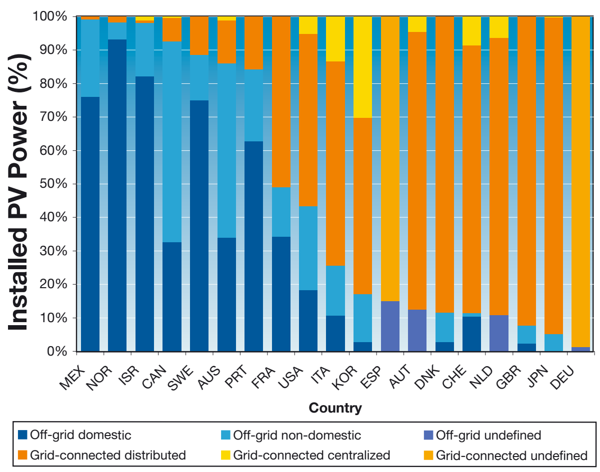

Figure 3 – Installed PV power in the reporting countries by application (%) in 2006

proportion of various PV applications in the reporting countries. Roughly one third of countries report off-grid applications as their dominant market. The types of off-grid applications vary between markets. For example, in Scandinavia, the most common off-grid applications are for vacation cottages, whilst in Australia, Canada and Mexico providing cost effective rural electrification tends to be the main aim. In all these markets, telecommunication and infrastructure applications are also important.

1.3 PV implementation highlights from selected counries

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

Australia (AUS)

The Australian PV market has been growing steadily over the past decade, assisted by government grant programmes, but began to increase markedly towards the end of 2006 when public awareness and discussion of climate change increased. From 2007 the PV market is expected to grow at a faster rate since Federal Government grant programmes have been extended or increased and several State Governments have announced local renewable energy targets. In addition, the four Solar Cities will begin installations in 2007 and, if their implementation models are successful, will result in a steady increase in PV uptake even after their original programmes are complete.

The largest installed capacity of PV in Australia is for off-grid industrial and agricultural applications. These include power systems for telecommunications, signaling, cathodic protection, water pumping and lighting. Significant markets also exist for off-grid residential and commercial power supplies and increasingly for fuel saving and peak load reduction on community diesel grid systems. Some of this market is supported by government grants aimed at reducing diesel fuel use.

A number of Australian Government programmes support the PV market in Australia. The most important ones are the PV Rebate Programme (PVRP) and the Renewable Remote Power Generation Programme (RRPGP). Some support is also provided via the Mandatory Renewable Energy Target (MRET) and Green Power programmes, while the Solar Cities Programme will begin to provide support from 2007. Several State Governments are considering feed-in tariffs for PV, although to date only the South Australian Government has put forward a proposal. State Governments have also put forward a proposal for an Emissions Trading scheme and for renewable energy targets on top of the MRET.

These programmes and proposals, in addition to the heightened awareness of climate change issues in the Australian community during 2006, served to stimulate the PV market towards the end of the year. With a federal government election in 2007, a number of commitments to continue PV support have already been made by the Government and the opposition parties. These include doubling the PV Rebate to 8 AUD/W to a cap of 8 000 AUD and extending the RRPGP.

Electricity utility interest in PV has been rekindled by the Solar Cities Programme, with three utilities now actively involved. In addition, the inclusion of fringe of grid locations in the eligibility list for RRPGP support has resulted in some interest in the use of PV for grid support. Four States are now examining options in this area.

The release of the Stern and IPCC Reports, Al Gore's film "An Inconvenient Truth" and the continuing drought in Australia have resulted in a sudden increase in media coverage and political interest in climate change, an issue the Australian Government had previously downplayed. Public interest is now high and new climate change programmes are expected to be announced in 2007. Key sectors which are already moving ahead include Local Government and several major building companies. Although PV remains a high cost option, because of Australia's low electricity prices, it is a more straightforward one for the community than many other energy options, with few aesthetic, noise, water or emission issues arising. Hence, with Australia's good solar resources and increased rebates, the PV market is expected to grow more rapidly over the coming year.

Austria (AUT)

To date public support schemes for PV in Austria have been mainly characterized by discontinuity. The domestic market situation for PV remains unclear and unsatisfactory. The revision of the main framework, the Green Electricity Act, which was agreed during 2006, does not provide any substantial support for PV implementation and further complicates the situation. Furthermore, no provisions for supporting special PV applications (such as BIPV niche markets) where Austrian companies could potentially achieve a strong competitive position have been made. However, despite the collapse of their home market, Austrian PV manufacturers again significantly expanded their business during 2006. By far the largest share of the Austrian production is exported to those European Union countries where attractive and stable incentives created a substantial market for PV.

During 2006 the decline of the domestic PV market continued further due to the absence of a federal incentive for PV market implementation. Following the all-time peak of 6,5 MW installed capacity in 2003, the annual PV market has been declining for three years in a row, dropping to 1,56 MW in 2006. This is the lowest figure since 2001.

Late in 2006 a revised feed-in tariff scheme under the Green Electricity Act 2006 came into effect. The whole support scheme, including applications, is now managed by OeMAG, a company established by the Austrian Ministry of Economy. However, as the first contracts were signed in November 2006, the new support scheme did not have a notable effect on the market in 2006. Some provinces are still running rebate programmes. These programmes were originally introduced in the period 2004 to 2005 to overcome the lack of federal incentives after the cap for federal support had been reached.

A major trend in PV projects implemented in recent years continued – optimal architectural integration of BIPV in newly constructed as well as refurbished buildings. Several installations with innovative design aesthetically integrated into buildings reflect this. An outstanding example is the community centre in Ludesch, Vorarlberg, which was realized under the framework of the national 'House of the Future' R&D programme. When the decision was taken by the municipal administration of Ludesch to build a new community centre, it was proposed as a representative example of an ecological building as well as a lively meeting place for the local people, with PV as a natural part of the concept. This PV solar roof is currently the largest PV system with semi-transparent solar cells in Austria. 350 m^2 of modules are covering the new village square – not only producing electricity but also protecting against rain and providing shade.

It is expected that the new regulations in Austria will lead to about 3 MW of PV being installed annually. However national PV stakeholders have questioned the effectiveness of the support framework mainly because of its complexity, and the modest financial limits which might not be able to significantly stimulate the domestic PV market.

Canada (CAN)

The Province of Ontario's Renewable Energy Standard Offer Programme (RESOP) launched in November 2006 is viewed by the Canadian PV industry as a major step towards developing a competitive, strong Canadian solar industry. The SOP in its initial stage will most likely stimulate the market leaders or "early adopters" to purchase PV systems and hopes to attract investment into the Canadian solar industry, with Ontario possibly becoming the economic centre of the solar industry in North America. The Programme provides a platform for all sectors of society to work together towards finding solutions to the energy challenges that the Province of Ontario will face in the coming years

The growth of the PV market in Canada has been averaging 25 % annually since 1993. In 2006 the largest module sales domestically occurred in the off-grid market (both residential and non-residential) with about 90 % of market share. This is an unsubsidized market that is growing because PV is meeting the off-grid electrical needs of customers in transportation signalling, navigational aids, off-grid homes, telecommunication, remote sensing, monitoring, and controlling.

However, the SOP is designed to encourage and promote the greater use of solar photovoltaic, as well as other renewable energy sources including wind, waterpower and biomass, that will be connected to the electricity distribution system of Ontario. To qualify under the SOP, the applicants must be willing to make the necessary investments in their facilities and in the costs of connection to the distribution system and metering, bear certain ongoing costs of operation and maintenance, and enter into a contract for electricity delivered for a 20 year payment period. The SOP guarantees payment of 0,42 CAD/kWh for grid-connected PV projects less than 10 MW for the term of the contract.

In August 2006, the City of Toronto installed a 100 kilowatt PV roof-top system – the largest solar power system in Canada – on the roof of the Horse Palace at Exhibition Place. The system is comprised of four subsystems, each using a different combination of solar, inverter and mounting technologies, which are expected to generate a combined 120 MWh of electricity per year. The electrical performance of each of the subsystems is separately monitored and compared, allowing Exhibition Place to determine the best overall combination of technologies for use in future projects. The performance data are available on a public website.

The Government of Canada through a TEAM-funded technology demonstration project is assisting Xantrex Technology Inc. to develop advanced control systems and platform that can enable photovoltaic, wind, fuel cells and alternative power systems to be optimally integrated into conventional fossil fuel-based power generating systems for remote and off-grid power applications. In August 2006 Xantrex installed its new solar Hybrid Power System in a demonstration project on the Xeni Gwet'in First Nation land near Chilko Lake, in a remote site located in central British Columbia.

Often due to a general lack of awareness and experience with PV technology, significant barriers to grid connected PV systems and other micro-power generators still exist for various stakeholders including utility companies, inspectors and regulators that perceive various technical risks associated with the technology.

Denmark (DNK)

With the completion of the SOL 1000 project at the end of 2006, Denmark was left without any incentives for reducing the capital cost of PV systems. However further deployment activities for grid-connected PV are expected to be developed in coming years. By the end of 2006 Denmark (including Greenland) had about 2,9 MW of PV installed, an increase of about 250 kW compared to 2005. Grid-connected distributed systems constitute about 90 % of the PV systems in Denmark.

The Danish government launched a new energy plan in March 2005. The energy plan focuses on a fully liberalized energy market supported by a framework which underpins high consumer and environment protection, energy efficiency, subdued development in energy prices and high security of supply, both in the short and long terms. With regard to renewable energy (RE) the plan sets quantifiable targets for the overall contribution from RE but no technology specific targets. Photovoltaic technology is not specifically mentioned in the government's energy plans, but early in 2004 the Danish Energy Authority (EA) in collaboration with the electricity sector, the industry and other key stakeholders finalized a national strategy on PV after a public hearing. This PV strategy includes the fields of research, development and demonstration.

The 1 000 roof-top programme was launched late 2001 as a follow up to the successful SOL 300 and targeted a mix of general cost reductions, increase in end-user payment and promotion of small roof-top systems. By the end of 2002 this utility programme reported a portfolio of some 1 300 house owners expressing firm interest in the programme stimulated by net-metering and an investment subsidy of 40 % of the turnkey system cost. The SOL 1000 project, originally targeting 1 MW of PV, realized about 600 kW by its completion at the end of 2006. A feature of these programmes has been their ability to drive down PV system prices compared to those being paid in most other countries.

Another interesting initiative is the sale of certified PV produced electricity without any subsidies or other external support by the utility Copenhagen Electric. The utility contracts to buy all electricity from new PV systems for the next 20 years at commercial terms and tries to sell this electricity to consumers in small standard packages. Even though the end-user cost of the certified PV electricity is three to four times that of standard electricity – ironically partly because of the present tax and duty structure – the scheme reports a small but slowly growing success.

The public interest for building integrated PV is increasing and most efforts are focused on developing and demonstrating PV in the context of existing buildings. A European Union directive on energy consumption in buildings has been developed into a revised national building code – moved into force early in 2006 – which specifically mentions PV and allocates PV electricity a factor of 2,5 in the calculation of the "energy foot print" of a building. However, due to inertia in the construction sector, it is too early to see any real impact on PV deployment.

France (FRA)

2006 was marked by important initiatives that have strengthened the legal and regulatory framework concerning photovoltaics in France. These include the Energy Planning Act that addresses energy management and the applications of renewable energy sources, the new solar photovoltaic research programme of the National Research Agency, the publication of new feed-in tariffs for PV electricity and an increase in the PV income tax credit for private individuals.

In 2006 the power of the systems installed in France during the year is estimated at 10,9 MW, the majority of which are connected to the grid (an increase of over 55 % compared to the previous year). The Finance Act which came into force early in 2006 contains the new financial subsidy system designed for private individuals installing a PV array on the roof of their homes. As a result, for private individuals subject to taxation, the fiscal measure consists of reimbursement covering up to 50 % of the costs of the materials (installation costs are excluded). The fiscal measure replaces the subsidies granted by ADEME to private individuals through its regional delegations.

A few regional Councils continue to allocate subsidies to the private individuals in the form of direct grants. For the private or public operators, the subsidy amount is granted on a case-by-case basis as part of calls for projects. In this case, ADEME is insisting on the quality of the architectural integration of the PV modules in the buildings when it is a new building and requires that a strong energy management policy be implemented. A feed-in tariff (which can be up to 0,55 EUR/kWh for BIPV) gives a strong boost to building integration and could allow robust and sustainable growth of the French BIPV market segment.

A significant project realized in 2006 was the photovoltaic power system of 1 MW capacity installed on the Réunion Island. This project was dedicated in December 2006 and should supply the Réunion Island with 1,3 GWh of electricity per year. The issue of energy independence in the French overseas departments has become a priority for the local political authorities and photovoltaics associated with a reduction in energy demand are the preferred solutions to this issue.

Office of Energy Syndicate of Drôme department (14 kW, photo courtesy Tenesol).

A strategy of the French authorities is to give a strong impetus to innovation in architectural integration in order that, in the long run, PV could become accepted among the construction industry companies as a common construction material in addition to generating electricity. Currently the market for PV applications is driven mostly by the investments from the local communities, with both the new feed-in tariffs and environmental concerns providing strong drivers.

Germany (DEU)

After a period of extraordinary growth rates the German annual market for PV slowed in 2006. This seemed to result from the shortage of feedstock silicon interacting with the relationship between system prices and the feed-in tariffs. However, for 2007 a significant expansion of the annual market is anticipated – possibly even reaching 2 GW of newly installed capacity. The German funding strategy favours the installation of grid-connected PV power systems. Grid-connected roof-top systems and large PV power plants continue to dominate the German market.

Just prior to publication of this report, the German Ministry of Environment (BMU) published a revised estimate of around 950 MW for the grid-connected capacity installed during 2006. At the same time revisions of the data for 2004 and 2005 were published by BMU. On the recommendation of the German IEA PVPS experts, the BMU data are accepted as the official German data for the purposes of this report. While the capacity installed in recent years is likely to remain a topic of discussion in Germany, there does now seem to be a general agreement. The uncertainty is due to the extremely high number of installations making it difficult to track individual systems.

The 'Electricity Feed Law' introduced in 1991 was replaced by the 'Renewable Energy Sources Act (EEG)' in April 2000. The EEG rules on the favourable payment for renewable electricity supplies to the electricity utilities. In 2004 the EEG was amended and the feed-in tariffs were adjusted. The tariffs for newly installed PV systems drop year by year by 5 %. For 2006 the basic PV tariff was 0,518 EUR/kWh. Façade integrated systems, for example, receive a bonus payment. The rates are guaranteed for a period of operation of 20 years.

In 2007 an evaluation of the EEG is scheduled that was pre-empted when this law was introduced. The evaluation has to be presented to the Parliament by the end of 2007. It will cover the status of the market introduction of renewable energies as well as the electricity production costs of these technologies. If necessary, an adaptation of feed-in tariffs and their regression rates will be suggested.

Following the close of the '100 000 Roof-tops Solar Electricity Programme' at the end of 2003, the support of PV systems through the provision of soft loans has been maintained under the 'Solar Power Generation' programme. Under this programme 30 284 loans representing a total volume of 237,4 MW, equivalent to 946,6 MEUR of investment, were granted since 2005.

Israel (ISR)

Typical new PV installations in 2006 in Israel remain the same as in previous years: remote homes, agriculture (computerized irrigation), security and alarm systems, communications and exterior lighting. Access to grid-electricity is almost universal, dependable and relatively inexpensive, and with an absence of PV support policies no grid-connected PV was reported installed during 2006.

In August 2006, the Israel Public Utility Authority – Electricity (PUA), issued its decision on solar rates, relevant for all solar technologies. The tariffs are normative, based on analysis of the costs of a solar-thermal plant – a well-known technology with low costs. Tariffs were established for installations of two different sizes: above 20 MW the tariff is 0,165 USD/kWh and between 100 kW and 20 MW the tariff is 0,206 USD/kWh. Tariffs are ensured for 20 years and will only be updated according to an automatic update formula. Additional support mechanisms are not calculated into the tariffs. A fossil element up to 30 % will be allowed. An electricity producer may sell to the Israel Electric Corporation or directly to a private customer. The assumption in formulating the tariffs was that after the first 250 MW to 300 MW installed, accumulated experience and new technological developments will be expressed in lower costs.

Italy (ITA)

The high demand for support (for about 100 MW of PV) recorded at the beginning of 2006 was well beyond the availability of the feed-in tariffs initially foreseen by the Ministry of the Economic Development (MED). Consequently a new MED decree was issued in February 2006 to accommodate a total of 500 MW, with an annual limit of 85 MW, in order to create a more stable situation. However, in spite of the large interest from designers, architects, investors and the general public, and the availability of generous feed-in tariffs, only a small fraction of the projects submitted to the Feed-in Tariff Programme have actually been realized.

The cumulative installed PV power in 2006 increased by about 12,5 MW reaching a total of almost 50 MW. Most of this increase has been due to the expansion of the grid-connected distributed market that now accounts for 60 % of the total power installed.

The decrees issued by the MED in July 2005 and revised in February 2006 include a feed-in tariff for the total electrical energy produced by the PV plant plus a value for any electricity that can be sold to the local electricity utility. These incentives apply to individuals, registered companies, public bodies and condominiums. In order to be eligible for the incentive scheme, PV plants must be connected to the low or medium voltage grid, range from 1 kW to 1 MW in size, use components which meet the technical standards, and begin operating within one year from the date of approval (or two years for plants larger than 50 kW). The first quarter of 2006 saw about 3 190 projects registered involving plants up to 50 kW (corresponding to about 91,2 MW) and 36 projects over 50 kW (corresponding to about 28,3 MW).

The tariff for the electricity produced varies with the nominal power of the plant and ranges from 0,445 EUR/kWh to 0,490 EUR/kWh. The duration of the support is 20 years and the tariffs are updated on a yearly basis, taking into account the official inflation rate. A tariff reduction of 5 %/year applies. The electricity produced by the PV plant can be used by the owner or sold to the local utility. A tariff increase of 10 % has been foreseen for PV systems integrated in building structures. For plants larger than 50 kW, the tariff is subject to a tender mechanism, which favours the tariff with a lower value. The decrees state that promotion tariffs are reduced by 30 % if combined with fiscal incentives, are not applicable to PV plants that have obtained incentives from public bodies exceeding 20 % of investment cost and are not compatible with green certificates.

The activities currently performed within the framework of the Demonstration Programme concern the analysis, tests, long term performance evaluations as well as operation and maintenance procedures carried out by ENEA (the Italian Agency for New Technology, Energy and Environment) on its own plants and on BIPV systems installed on public buildings of municipalities and universities in some prominent Italian cities. Furthermore, performance evaluations of PV components and plants are carried out by CESI RICERCA (the Institute for Research on Electricity and the Energy sector) in order to

PV system at parking lot in Fujipream, Japan

assess long-term behaviour of PV technology in different climatic conditions and in different electrical configurations.

Several utilities continue to support the implementation of photovoltaic distributed generation, co-operating with ENEA, CESI RICERCA, installers and inverter producers, to overcome some grid interface technical barriers which can lead to an increase in costs.

Japan (JPN)

During 2006 the annual PV market growth in Japan stagnated, being much the same new capacity as that installed the previous year. The main factors cited are the end of financial support through the 'Residential PV System Dissemination Programme' the previous year and indirect effects of tight silicon feedstock supply. The market for residential PV systems (accounting for almost 89 % of the whole market) has now shifted to be largely self-supported, driven by market mechanisms. The sale of prefabricated houses equipped with PV systems as standard equipment has been implemented by many housing manufacturers and local developers. Additionally, the implementation of PV systems on collective housing is underway. Battery manufacturers, building material manufacturers and construction companies are now likewise engaged.

The total annual installed capacity in 2006 was about 287 MW. Major applications of the grid-connected distributed market are private houses, apartment houses, public, industrial and commercial facilities and buildings. The volume of all these application areas has expanded year after year mainly as a result of the Ministry of Economy, Trade and Industry (METI) support measures. The development of the Japanese PV market has been based initially on 3 kW to 5 kW residential PV systems and, particularly from 2006, 10 kW to 1 000 kW systems for public facilities, industrial facilities and commercial buildings.

In the off-grid domestic market there are PV applications for mountain cottages, islands and certain applications for public and industrial uses, but the market scale is quite small. The main PV applications in the off-grid non-domestic market include power supplies for street lighting, telecommunication, remote monitoring, water pumping, emergency power for disaster relief, agriculture, traffic signs, ventilating fans and the like. The off-grid non-domestic market in Japan has already been established as a commercial market that does not require subsidy.

While METI did not commence new initiatives during 2006, the following programmes received continued support: 'Field Test Project on New Photovoltaic Power Generation Technology', 'Project for Promoting the Local Introduction of New Energy' and 'Project for Supporting New Energy Operators'. The 'Field Test Project on New Photovoltaic Power Generation Technology' aims to adopt new technologies into PV systems for public and industrial facilities and accelerate further development, while promoting further introduction of medium and large-scale PV systems. Eligible applicants for the projects are private businesses, local authorities and organizations. As co-researchers, they collect performance data for 4 years and demonstrate the performance of the PV system. 50 % of the installation cost is subsidized. Under the Field Test, 662 PV systems accounting for 22 080 kW were installed in 2006. The cumulative installed capacity of PV systems introduced by Field Test Projects since 1992 is expected to be about 74 000 kW.

The ‘Project for Promoting the Local Introduction of New Energy’ aims to accelerate new energy introduction by supporting the regional and nonprofit projects established by local governments and nonprofit organizations respectively. In 2006, 35 PV projects (1 130 kW in total) were accepted for city halls and water treatment plants, primary and junior high schools, kindergartens and so on.

The ‘Project for Supporting New Energy Operators’ aims to accelerate new energy introduction by supporting the businesses that launch the introduction of new energy from the perspective of energy security and global environmental protection. The capacity of eligible PV system is designated as 50 kW or more (or in the case of multiple installations of different technologies, a PV system with capacity of 10 kW or more is also eligible). Eligible parties are private businesses. A maximum of one third of the system installation cost is subsidized, to a maximum of 1 billion JPY, and debt is also guaranteed. In 2006, two PV projects totaling 160 kW were selected. While PV systems are mainly introduced to factories and headquarters buildings under the Project, PV systems for all-electrified condominium buildings have also been installed.

A joint METI, Ministry of Education, Culture, Sports, Science and Technology (MEXT), Agriculture, Forestry and Fisheries Ministry (MAFF) and Ministry of the Environment (MoE) project, ‘Eco-school Promotion Pilot Model Project’, aims to implement pilot model projects to promote the introduction and demonstration of environmental-friendly schools, providing students with environmental education and improving school facilities. MEXT provides subsidy for planning investigations, half the cost of new construction of the school and one third of the cost for rebuilding or retrofitting. METI’s subsidies described above are available for the PV system installation in either new construction or renovation of schools. 387 schools in total have been approved for PV system installation, with 44 schools approved in 2006.

The Ministry of the Environment started the ‘Solar Promotion Programme’, a package of several projects to advance countermeasures against global warming, including dissemination programmes within each project to promote the introduction of PV systems.

Japanese electricity utilities have voluntarily offered net billing since 1992 to buy back surplus electricity generated by PV at the selling price of electricity across the country. Electricity utilities also introduced the ‘Green Power Fund’ based on contributions from supporting customers. The fund is utilized to introduce PV and wind power plants, and during financial year 2006 149 PV projects totaling 2 162 kW in total were developed. The utilities are also required by law to purchase specific amounts of renewable energy under a Renewable Portfolio Standard (RPS). By March 2006 accredited renewable plant included 265 963 PV systems amounting to 988 MW of generation capacity.

The awareness and perceptions concerning PV are becoming more and more positive over time as a result of the PV promotion initiatives and publicity through television and newspapers. Additionally, the willingness of businesses to invest in environmental solutions is increasing. Local governments have become active in the introduction of PV systems and have established their own new frameworks to accelerate the deployment of residential PV. This includes a subsidy according to the excess PV electricity produced and green electricity certificates for the in-house consumption component, plus a subsidy based on installed capacity.

Housing manufacturers, building material manufacturers, construction companies and power supply equipment manufacturers are developing products using PV systems. Local electrical equipment stores, electrical appliance stores, building contractors, roofers, etc also promote the sale and installation of PV systems. A comprehensive distribution chain for residential PV systems, from cell manufacturers to the end-users now exists.

Korea (KOR)

Under Korea‘s new national PV plan, the goal has increased to 100 000 PV roofs and 70 000 buildings with PV providing a total capacity of 1,3 GW, by the year 2012. Explosive market growth is expected between 2006 and 2012. The foundation for mass deployment of PV was set in place in 2006, especially for roof-top applications and the feed-in tariff market. In the future the BIPV market is expected to play an important role as a result of specific Government initiatives.

The cumulative installed PV power increased dramatically to 34,7 MW by the end of 2006. After surpassing the 1 MW landmark for the first time in 2005, with a figure of 4,99 MW, the annual installed power in 2006 reached 21,3 MW which was more than four times higher than that achieved in the previous year. The majority of the increase came from PV power plants supported by the feed-in tariff and 3 kW residential roof-top applications under the 100 000 solar roof programme. The share of grid-connected distributed systems increased to 83 % of the total cumulative installed power from 58 % the previous year. In 2006, the annual installed power of this sector was 20,93 MW, representing over 98 % of the total Korean PV market.

In its third year of the ten year plan, the Korean Photovoltaic Programme made significant progress in the areas of system installation, R&D investment, and standards and accreditation. The feed-in tariff rate per kWh changed from 716,40 KRW to 677,38 KRW for systems larger than 30 kW. Under the feed-in-tariff programme, 52 commercial PV power plants of 9 157 kW in total (ranging from 3 kW to 1 MW in size) were newly installed and commenced operation. Four 1 MW PV plant were installed – the Donghae PV power owned by Dongseo utility, Youngheung PV Power owned by Namdong utility, Kangjin PV Power owned by Namhae Energy and Hanra PV Power owned by Hanra Electric Co. Ltd. The 2006 annual spending for the feed-in tariff programme amounted to 3 478 million KRW and the annual PV power generation was 5 474 MWh.

Under the 100 000 roof-top programme in 2006, 2 452 systems (total capacity 6 469 kW) were installed on single-family houses. In addition, 120 kW systems for apartment blocks and 3 kW systems for public rental apartments were installed. PV systems on multi-family apartments were a new application in 2006 and it is expected that this will be a popular market. Under the programme, beneficiaries pay 30 % of the total system price of 8,55 million KRW per kW.

In addition various grid-connected PV systems with a power capacity of 5 kW to 200 kW were installed in schools, public facilities, welfare facilities and universities under the 'General Deployment Programme'. The government supports 70 % of the installation cost. In 2006, 77 systems totaling 2 255 kW were installed. New public buildings larger than 3 000 m^2 must spend 5 % of total construction budget installing a renewable energy facility under the 'Public Building Obligation Programme'. From its start in 2004 up to November 2006, a total of 349,1 kW of PV were installed. Under the local energy development project, a wide variety of PV systems including off-grid domestic, non-domestic and grid-connected systems were constructed. In 2006, 27 PV systems totaling 1 831 kW were installed with the aims of increasing public awareness of PV and developing PV as an indigenous renewable energy source.

Korea has several projects of multi-MW scale in the planning stage with local governments and local utilities or foreign companies. Several local authorities finished nine 'Green Village' projects, composed mainly of PV, solar thermal, geothermal and wind power by the end of 2006. During 2006, two new green village projects were implemented – Buyeo of Chungchung nam-do province and Suncheon of Chunla nam-do province.

Malaysia

2006 was a year of preparation of 'soft infrastructure' for PV growth in Malaysia, including promoting PV awareness, building capacity within the industry and developing the financial incentive programme. As a result, the net growth of PV was very low, only 4,52 kW. A much higher PV growth is expected in year 2007 with the completion of some showcase, demonstration and SURIA 1000 projects.

The SURIA 1000 Programme provides attractive financial discounts for homeowners wanting to integrate PV into their homes. The programme operates on a bidding process. Under the first call the potential discount is as high as 75 % of the BIPV system price. This discount will be covered by the government through the Energy Commission. Between December 2006 and the end of 2010 there will be nine calls for biddings, with one call specifically focused towards property developers. The calls will be opened to the public every six months, with the percentage of maximum discounts diminishing with each call.

Alongside the financial incentives, an industry association – Malaysian PV Industry Association – has been established with support from the Malaysian Building Integrated PV (MBIPV) Project. The objectives of MPIA are to establish PV industry best practices, and to engage in capacity building for those in the industry and awareness raising for members of the public.

The Netherlands (NLD)

The Dutch Government mainly sees a role for PV electricity in the longer term, after 2010. Consequently the government does not specifically support the implementation of PV but instead focuses on research and development aimed at PV cost reduction over time. In 2006 however the Sustainable Electricity Production Platform appointed PV as one of the energy transition paths. This may result in a renewed interest in PV in 2007 and possibly in a limited implementation support scheme in order to enable the market players to prepare for the future large scale deployment of PV.

The annual market for PV in the Netherlands decreased by almost 10 % from 1,66 MW installed in 2005 to 1,5 MW installed in 2006. There was a 20 % decrease in the market for distributed grid-connected systems, which was partly compensated by 0,160 MW of new centralized grid-connected systems. The market for the distributed grid-connected systems (1,08 MW) was mainly generated by local and regional incentive schemes, which provided investment subsidies of up to 3,00 EUR per W. Though the market for off-grid systems also fell by 14 % it appeared to revive at the end of 2006.

The policy for PV in the Netherlands is focused on cost reduction through research and development. This is well reflected in the budgets spent on PV in 2006: 94 % (9,40 MEUR) of the total national spending for PV went to research and development, while only 0,6 % and 5,4 % were spent on tax and green certificate incentives for implementation respectively. Besides the national funding, around 2,5 million Euros (MEUR) of investment subsidies were provided by local and regional authorities. Examples of initiatives organized by local authorities and electricity utilities include: the municipality of Zeist supported PV installations with a subsidy of 1,00 EUR per W; the Municipality of Alkmaar supported PV installations with a subsidy of 3,00 EUR per W; the electricity company Delta supported PV with a subsidy of 1,00 EUR per W for inhabitants of the province of Zeeland.

A new scheme, the EOS ES (Energy Research Subsidy – Energy Collaboration Subsidy) proved relatively fruitful for PV: 2 projects were granted in 2006, with an average support of 1,2 MEUR per project. The BANS (Public Administration Agreement New Style) agreement, which supports municipalities and provinces to stimulate energy reduction, resulted in several initiatives of local authorities to support amongst other things the implementation of PV. Apart from these some generic sustainability support measures addressed the application of PV. These include two feed-in regulations and one tax rebate regulation.

PV is still considered as one of the most attractive renewable energy options in the Netherlands. Building-integrated PV in particular is seen as a significant potential contributor to future Dutch electricity production. As the price of PV electricity however is still around 0,50 EUR/kWh the public is waiting for PV prices to go down, or an incentive to start, before purchasing a PV system. The electricity utilities also see the future possibilities of PV. Two invested in PV in 2006: NUON took over the Heliantos thin film silicon cell pilot plant from AKZO and Delta invested in a new ECN spin-off company called GS Development.

Norway (NOR)

The highlight for PV in Norway in 2006 is the same as for 2003, 2004 and 2005 – the remarkable positive industrial development by Renewable Energy Corporation (REC).

The main market for PV in Norway continues to be related to off-grid applications. This refers to both the leisure market (cabins, leisure boats) and the professional market (primarily lighthouses/lanterns along the coast and telecommunication systems). Up to 1992, the demand for PV installations in cabins and recreational homes on the coast, in the forests and in the mountains of Norway constituted the most important market segment. After 1992, this market slowed due to saturation. During the last 20 years, size and comfort of the Norwegian cabins have increased significantly. A number of cabins are equipped with 300 – 400 W panels, and sometimes even more. A few cabins have been equipped with comparably large PV systems of about 600 W. These systems have a 12 V installation for lighting and inverters for supplying 230 V AC to conventional power outlets. They may also have a small gasoline or diesel fuelled generator for peak supply and backup.

In the period after 1992, the slowdown in the leisure market was partly compensated by demand from professional users, for example PV powered coastal lighthouses. Even north of 70° longitude lighthouses are powered by PV and are provided with a NiCd battery-bank that ensures power supply during the dark winter months. A typical storage capacity is 120 days without power from the PV system. Approximately 2 620 installations serving lighthouses and coastal lanterns have been implemented. The smallest are equipped with one single module of 60 W, the largest with arrays of up to 88 modules. The average is 135 W per installation. Applications of stand-alone PV for telecommunication stations and hybrid utility systems have also grown during the past years.

The largest building integrated PV project so far in Norway was built during 2006 and consists of transparent double glass modules on the southern façade of the new Oslo opera house, located in the harbor area. The 35 kW system will serve partly as a solar shading device and will partly be integrated in the building façade. This is part of an EU project 'EcoCulture'. The system will deliver approximately 22 000 kWh/year. In October 2006, a 17,5 kW PV system was installed at the Oslo Innovation Centre near the University of Oslo.

Norwegian electricity utilities have made some selective investments for providing electricity to remote dwellings. PV in combination with other energy sources has been demonstrated for permanent dwellings and offers a viable solution in Norway where the distance to the existing electricity grid exceeds 10 km.

Spain (ESP)

2006 was somewhat of a transition year in Spain, with the activity developed under a 2004 Royal Decree being superseded by the announcement in another Royal Decree of a new feed-in tariff scheme. However it has been demonstrated that the new scheme is working satisfactorily enough and the deployment of PV has gained strong momentum. In 2006, there were 63 MW of PV installed – two and a half times the amount installed in 2005. Currently the distribution of the PV installations in Spain is about 85 % grid-connected systems and 15 % off-grid systems.

The Spanish national programmes favour the installation of grid-connected PV and this has led to fewer installations of off-grid applications. Installation and system companies, and the great majority of manufacturers, focus on the installation of grid-connected systems. Within the grid-connected PV power applications the distributed systems dominate.

The main support framework in Spain is the feed-in tariff scheme, with the following main characteristics: long term, with a fixed tariff for the full duration of the contract, providing a current internal rate of return > 7 %, revision every four years to evaluate the market progress, review the tariffs and the internal rate of return for the coming years, simple system, and without differences between locations with differences of irradiation. Much of the growth that will be encouraged by this scheme will come from Huertas Solares projects – large PV farms with many individual PV systems ranging from 5 kW to 100 kW. The PV systems are owned by private investors.

In addition, a new Royal Decree was approved that provides a Technical Building Code (TBC) establishing obligatory requirements to be met by buildings. A section of the TBC regulates the incorporation of solar PV energy and enforces the installation of PV on new large buildings, such as offices, government buildings, hospitals etc. In given buildings the PV electricity may be for own use or supply to the grid. The minimum PV capacity required in each case will depend on the climatic zone, the building floor area and the building use.

Some demonstration projects include: a 76 kW installation in Torre Garena with the building's façade and roof incorporating two different PV systems integrated into the building's design; 25 kW high solar concentration (250x) with tracking at the Polytechnic University of Madrid; Phase II of the project 'Solarizate' which consists of installation of 50 PV plants in comprehensive schools and in high schools, each plant to have remote monitoring; 1 kW high solar concentration (550x) with tracking, for long-term testing. Also worth mentioning are the large, conventional plants begun in 2006: the 20 MW PV system in Trujillo, Cáceres, costing 150 MEUR and covering an area of about 100 ha and the 'La Magascona' project that will use 200 100 kW units to qualify for the highest feed-in tariff for this type of plant. A number of projects using high concentration technology are also underway, and will provide capacity of about 3,5 MW.

Sweden (SWE)

The most important development in Swedish PV applications during 2006 was the strong increase in the amount of grid-connected systems installed. Previously, only a few projects often totaling less than 50 kW were installed each year but the investment subsidy for public buildings has changed this. The total amount of grid-connected distributed PV installed amounted to 300 kW in 2006, which means that it was the first year in which the grid-connected and off-grid markets were of equal size. Due to the investment subsidy the awareness of PV with property managers, architects, builders, etc., has generally increased, although from a very low level. Previously, PV was of interest mostly to energy and building companies but with the introduction of the support system more stakeholders have become involved in the PV business.

The investment subsidy for public buildings, which was launched in May 2005, is capped at 150 MSEK and will amount to approximately 3 MW if fully subscribed. Initially 100 MSEK was allocated to support PV installations in buildings for public use. In the projects eligible for support 70 % of the total project cost, including external project management costs, is covered by the investment subsidy. In the 2006 economic bills the total cap was raised to the current 150 MSEK and the time-frame was extended to the end of 2008. The nature of the support was changed from being a tax reduction to a direct capital support. This was mostly a budget technicality and does not change the effect of the legislation.

The city of Malmö in the southernmost part of Sweden has shown interest in PV for a couple of years and has executed several projects within the investment subsidy programme. By the end of 2006, the 68,9 kW PV system at the Technology and Maritime House in Malmö was the largest PV system installed in Sweden. Eksta Bostads AB is a municipal housing company that was one of the first property managers to apply for the investment subsidy when it was launched in 2005. This resulted in a 64 kW installation on the roof of a primary health care centre in Fjärås, inaugurated in April 2006. The health care centre only uses renewable energy and over the course of a year a surplus of electricity is produced and exported to the utility network. The city of Stockholm decided to fund an additional 30 % of the project cost for PV systems if municipal companies were interested in applying for the investment subsidy. In principle this would make the PV investment fully-funded for the owner of the system. This led to a number of projects being planned, although several property managers were still reluctant to embrace PV technology. A few of these projects have been delayed since there have been problems obtaining building permits.

Solar thermal and PV have enjoyed wide public support, with roughly three quarters of the population wanting more support for solar energy projects. In light of the recent discussions on global climate change, the support for solar energy has increased even further during 2006. A common misconception is that a lack of insolation in Sweden makes it less favorable to use solar energy compared to continental Europe. However, the yield of a PV system over a year is more or less the same in southern Sweden as in large parts of western and central Europe. The Swedish electricity utilities have widely different perceptions of and attitudes towards renewable energy. Some have a distinct renewable energy profile while others show little interest in accommodating new renewable energy generation.

Some utilities and electric companies are directly or indirectly involved in PV research, development and demonstration.

Switzerland (CHE)

In 2006 the PV market in Switzerland was driven mainly by small- to medium-size grid-connected systems: 250 new installations in comparison to 2005 with 200 installations. The majority of PV installations are grid-connected plant, built mostly on the roofs of buildings. Larger installations (> 50 kW) are usually flat-roof mounted on commercial buildings, offices etc. The smaller grid-connected PV installations (typically around 3 kW) can normally be found on the roofs of single family homes. Traditionally, off-grid installations for weekend chalets and alpine huts are relatively small (< 1 kW).

Due to the lack of new large PV projects such as those installed in the previous year, for example 1 MW in Geneva and 850 kW on the football stadium in Berne, the annual installed capacity in 2006 was only 2,5 MW compared to the 4 MW installed in 2005. Also, during 2006, potential investors were waiting for the decision by the Swiss parliament regarding the new feed-in tariff law, which will finally be introduced in the second half of 2008.

Sales of PV electricity on the solar stock exchange scheme again increased which will lead to at least another 2 MW of new PV being installed during 2007. The electricity utility of the city of Zurich (EWZ) has contracted a further 1,7 MW under this scheme.

Private investors, together with a large utility, started a project for cell and module production in Switzerland. According to media releases, the Solar Plant Swiss will start production within two years. Currently, the Swiss PV industry is focused on production equipment manufacturing and BOS components.

With the small domestic market, the Swiss BOS industry benefits from the strong German and growing Spanish markets and the equipment manufacturers are receiving strong demand from newly-established production capacity in Asia. The estimated turnover of the whole PV industry amounts to about 400 million CHF. In the wire saw markets, the two companies Meyer Burger AG and HCT Shaping Systems AG held their lead in the global market. Oerlikon Solar successfully sold its thin film manufacturing line with orders through the end of 2006 amounting to several hundred million CHF. The growing awareness of investors is reflected in the successful IPO of Meyer Burger AG and the rising shares of Oerlikon and 3S.

United Kingdom (GBR)

During 2006, the UK government launched its Microgeneration Strategy for Great Britain. The term microgeneration includes PV, small wind turbines, micro hydro, solar thermal, ground/water/air source heat pumps, bio-energy, renewable combined heat and power (CHP), micro-CHP and fuel cells. The objective of the new strategy is to create conditions under which microgeneration becomes a realistic alternative or supplementary energy generation source for the householder, communities and small businesses. Its wide ranging actions include an accreditation scheme for products and installers, a review of planning procedures, a pilot to assess the benefits of smart metering, as well as the new Low Carbon Buildings Programme. The Low Carbon Buildings Programme, also launched during 2006, provides grants for microgeneration technologies including PV for householders, community organizations, schools, the public sector and businesses. A total of 80 MGBP was announced for the three year programme, with 50 MGBP to be used for installations on large-scale public buildings. The new grants programme replaces the PV Major Demonstration Programme (MDP) which ran from 2002 and closed for new grant applications in 2006. The MDP provided funding for over 70 % of PV installations in the UK during 2006.

In Northern Ireland, where energy is the responsibility of the Northern Ireland Assembly, the Energy and Environment Fund was launched in February 2006. This package of funding includes 8 MGBP over two years for householders installing renewable energy systems including PV. Additional funding is made available for promotion of renewable energy.

Other highlights include the Code for Sustainable Homes, a voluntary initiative in England, by government and industry, to actively promote the transformation of the building industry towards more sustainable practices. The code was launched by the Department for Communities and Local Government in December 2006. There are minimum standards for energy and water efficiency at every level of the

PV cladding is part of the new Manchester College of Arts and Technology (MANCAT) building, UK

Code, with the lowest levels raised above the level of mandatory building regulations. The higher levels of the code require the installation of microgeneration technologies such as PV.

Local planning policies requiring new developments or refurbishments to include on-site renewables have also become increasingly important in encouraging PV as well as other small-scale renewables. Of the 410 local councils in England and Wales, 19 have adopted such a policy (usually placing a requirement on developments over 1 000 m^2 to reduce carbon dioxide emissions from building energy use by 10 % over the minimum standards of the building regulations), and over 100 councils are actively progressing the introduction of such a policy. In Scotland, 2006 saw the development of a new draft Planning Policy on renewable energy. Developments with a total floor space of 500 m^2 or more will need to incorporate on-site renewables or CHP to contribute at least an extra 15 % reduction in CO_2 emissions beyond the 2007 building regulations requirements.

While many of the large electricity utilities have announced their support of microgeneration technologies including PV, seeing potential particularly within the domestic market, export tariffs for the electricity generated vary widely between different electricity suppliers. Arrangements are structured in different ways making comparison difficult for consumers. Domestic customers may be offered around 0,06 to 0,08 GBP/kWh for export, which is similar or less than the average retail price of electricity. Alternatively between 0,035 and 0,045 GBP/kWh for total generation may be offered. Many such preferential rates are available only to domestic customers. Northern Ireland Electricity continued to offer top up grants for PV installations in Northern Ireland during 2006, providing an extra 15 % of the total capital cost in addition to the government grants.

United States of America (USA)

The years 2006 and 2007 represent a ramping-up of political discussions in preparation for the 2008 US Presidential election. Energy security and climate change are bipartisan issues that have already been elevated to the top of the national political agenda. Diversification of energy sources and conservation are already emerging as common themes in security and climate discussions. As pro-solar policies are implemented at state and local government levels, PV is poised to become a bigger player in the energy mix.

PV applications in the United States grew by 38 % to 145 MW in 2006. Off-grid consumer sector installations amounted to more than 14 MW in 2006 and include PV for remote residences, boats, motor homes, travel trailers, vacation cottages, and farms where connecting to the electricity grid is not feasible or practical. The off-grid commercial/industrial sector saw 23 MW installed in 2006. Telecommunications, sensor power sources and data communication power, security phones on highways and parking lots, traffic monitors, remote lighting and signals, inter-coastal navigation aids and supplemental lighting sources for environmentally-friendly corporate headquarters are all covered by this sector. PV also serves a broad array of applications for local, state, and federal government. These include large PV/diesel hybrid power stations where grid connections are not practical as well as smaller systems for the types of applications mentioned above. The grid-connected distributed sector grew 54 % from 65 MW in 2005 to over 100 MW in 2006, primarily in both the grid-connected residential and commercial sectors. It is believed that this sector growth was the result of the growing popularity of state tax credits and rebates and the Federal Tax Credit. California led the way with more than 65 MW of grid-connected systems installed in 2006.

According to a report by the Interstate Renewable Energy Council (IREC), U.S. state-supported PV installations grew from 63,6 MW in 2005 to over 101 MW in 2006. The transition to the new California Solar Initiative (CSI), a 10-year, 3 000 MW programme to be managed by the California Energy Commission (CEC), commenced in 2006. One objective of the programme is to decrease the subsidy each year, to stimulate lower installed PV system costs so that PV is economical without subsidy by or before 2016. The original bill allotted 2,9 billion USD for solar energy rebates in California over 10 years. The goal is to increase the PV capacity installed on California roof-tops by 3 000 MW by 2017.

President Bush announced the Advanced Energy Initiative in his State of the Union Address in January 2006 and promised more aggressive renewable energy policy and research efforts by the Federal government to diversify U.S. energy sources and mitigate climate change among other reasons. In response, the Solar America Initiative (SAI) was created by the U.S. Department of Energy to accelerate manufacturing, cost, and commercialization goals for solar energy technologies. Additionally, Federal tax credits for PV went into effect in 2006 and include a 30 % investment tax credit for commercial grid-connected systems and a 30 % tax credit for residential grid-connected PV systems with an annual cap of 2 000 USD per system.

Owing to the fact that all US electricity generation is a states rights issue, all utility policy and regulation comes under state rule. States are playing an increasingly important role in the deployment of PV. Policy issues related to PV include: restructuring, net metering, on-site generation (residential and commercial), interconnection standards, insurance, taxes, and subsidies. Fourteen states have established clean-energy funds that are typically funded by a small surcharge on retail electricity rates to promote the development and commercialization of renewable energy technologies. Many of these subsidies take the form of renewable power set asides and direct tax credits at local and state levels. The total value of these incentives was more than 300 million USD in 2006. Details on these varied and complex codes, laws, and incentives can be found at www.dsireusa.org.

Another important government-related programme is the "PV for Schools" programme to install PV systems on educational buildings and increase students' and consumers' awareness about solar energy. Other forms of marketing incentives and deployment techniques include: the availability of PV systems as a standard feature for new homes by homebuilders through GE Energy, BP Solar, PowerLight, and larger PV system integrators in certain U.S. home markets, and expanded in-store sales of packaged, grid-connected PV systems through big box retailers such as Home Depot, a major home improvement retailer.

Other countries

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

Bangladesh
The solar PV market in Bangladesh is dominated by the Solar Energy Programme under the World Bank/GEF/KfW/GTZ Rural Electrification and Renewable Energy Development Project (REREDP). The project is managed by the Infrastructure Development Company Limited (IDCOL), which provides refinancing, technical assistance and training to 15 partner organizations (POs), who sell solar home systems (SHS) to householders and businesses in remote and rural areas. Typically this is via a micro-credit arrangement. IDCOL's initial target was to finance 50 000 SHS by the end of June 2008. The target was surpassed three years ahead of schedule and a revised target of 200 000 SHS by 2009 has been established. Most active amongst the POs to date is Grameen Shakti, which has financed over 73 000 SHS sales (over 3,6 MW) up to May 2007. Bangladesh Rural Advancement Committee (BRAC) has supported sales of more than 25 000 systems, with the other POs accounting for a further 18 000 systems to date.

China
Despite some delays to the start of the Song Dian Dao Cun (National Village Electrification Programme), which is undergoing a design review and is expected to commence in late 2007 / early 2008, China experienced strong growth in its domestic PV market in 2006. 15 MW of new capacity were reportedly installed taking the cumulative capacity to date to 85 MW and making China the world's sixth largest market for PV modules in 2006. Note that China's total cumulative capacity includes more than 12 MW of 'PV products' (calculators, garden lights, torches, etc.); this category of application is not generally reported by IEA PVPS countries and is not included in the applications analysis presented in this report. Delays have also been experienced with implementation of some aspects of the Renewable Energy Law (REL) that came into force at the beginning of 2006. Some of the mechanisms announced in the REL have still to be defined in detail, for example the arrangements for cost sharing of off-grid renewable energy incentives amongst all electricity customers. Potentially this would enable off-grid systems to benefit from the REL tariffs and their costs to be shared amongst all Chinese electricity customers. On the positive side, a new government notice has clearly identified rural electrification to be the responsibility of the power companies, and some have made plans to start implementing rural electrification projects this year, with renewable energy individual household systems and village systems the chief approaches for off-grid electrification.

European Union –
New Member and Candidate States
Other EU countries outside of IEA PVPS added some 4,6 MW of new PV generation capacity in 2006, according to the EurObserv'ER Photovoltaic Barometer (April 2007), taking the total EU non-PVPS country capacity to almost 41,7 MW. Belgium accounted for almost half (2,1 MW) of the new installed plant, all of this being in grid-connected applications. Greece contributed an additional 1,25 MW though, in contrast to all other EU non-PVPS countries, the vast majority of this (84 %) was off-grid, while Cyprus added over half a MW. Luxembourg had virtually no new generation capacity (just over 40 kW) installed in 2006, yet remains the EU country with the largest installed capacity outside of IEA PVPS with 23,6 MW. It also retains its position as the country with the world's highest installed PV capacity per capita at almost 51,4 W per inhabitant.

India
During 2005-06, India introduced two new initiatives, the National Electricity Policy and the Rajiv Gandhi Gramin Vidyutikaran Yojana (RGGVY), both of which have important implications for rural electrification.

In particular, RGGVY is targeting electricity access to all households by 2012, with the exception of homes in certain remote villages. Under the 2006 rural electrification policy, a 'minimum lifeline' access to electricity of 1 kWh per household per day is called for. The Remote Village Electrification Programme under the Ministry of New and Renewable Energy (formerly MNES), which had been pursuing electrification based on solar PV lighting systems, was modified to align it with RGGVY and now applies only to those villages not likely to receive grid connection. PV home-lighting systems are now viewed as an interim electrification solution. Nevertheless, this is still likely to imply some 900 000 households will receive solar home lighting systems under the 11th Plan (2007-2012). In 2006, reportedly 60 000 PV home-lighting systems, 6 000 PV street lights and 27 500 solar lanterns were allocated under the government subsidy programmes. A further 300 kW of larger-scale stand-alone plants and some 90 kW of PV pumps, as well as almost 200 kW of grid-connected PV were also supported by MNRE. In the past, the Ministry's programmes have typically accounted for around half of the total installed national PV capacity.

Nepal
Over 60 000 solar home systems, amounting to 2 MW of generation capacity, were installed in Nepal between 2001 and end of 2005 with subsidies under the Solar Support Programme of the Energy Sector Assistance Programme (Danish and Norwegian funding). ESAP is now entering Phase Two, which will provide additional funds to help subsidize a further 150 000 SHS and 250 000 'solar tukis' over the five years from 2007 to 2011. The tukis are an entry-level white LED lighting system using a 2 – 5 W solar module, designed for situations where SHS and other electrification remains difficult or unaffordable. An Interim Renewable Energy Fund was established to bridge the gap between the end of phase 1 in 2005 and the start of the second phase in 2007. Funds were set aside to support a nominal 10 000 additional solar home systems. By mid May 2007, almost 13 000 SHS had registered for interim subsidies.

Sri Lanka
Approximately 3,6 MW of PV solar home systems (over 80 000 units) have been installed in Sri Lanka to the end of 2006 under the five-year Renewable Energy for Rural Economic Development (RERED) Project. The success of RERED, which builds on the Energy Services Delivery Project that delivered almost 1 MW of PV to 21 000 households between 1997 and 2002 and which is due to conclude at the end of 2007, has recently prompted the World Bank to approve additional financing for further renewable energy developments in Sri Lanka. Specifically a further 60,000 rural households will benefit from off-grid electricity services.

Thailand
Thailand has been receiving noticeable attention in the last few years as one of the countries considered to be an important near-term non-OECD market for solar PV applications. This interest was largely based on a programme for roll-out of 24 MW of PV to some 200 000 remote homes during 2004 and 2005, and a stated target of 250 MW of PV to be installed nationwide by 2011. The latter target included a significant grid-connected component, notably 140 MW to be installed as part of the 5 % renewable portfolio standard for electricity generation. The country is not an insignificant PV player, given 30 MW have reportedly been installed to date (comparable to Switzerland, for example). However, the 2011 target for total installed PV has recently been considerably pared back to just 55 MW, which will dampen enthusiasm for project developments.

1.4 Budgets for market stimulation, R&D and demonstration

The public budgets for market stimulation, research and development, and demonstration and field trials in 2006 in the IEA PVPS countries varies from country to country (see Table 4 for 2006 budgets) and the boundaries of what constitutes 'research', 'development', 'demonstration / field trials' and 'market stimulation measures' often vary as well. The reader is directed to the individual national reports on the public website for a comprehensive summary of R&D activities in each of the countries. General information on the national market stimulation initiatives can be found in section 1.3.

2006 saw a large increase in total budget compared to 2005, to over 2 billion USD. While this was largely due to the increasing amounts being paid under feed-in tariff schemes, such as in Germany, and other market stimulation measures, expenditure on RD&D also increased by about 17 %. Nearly all countries reported increases in total expenditure for 2006 compared to 2005. Besides the obvious increase in Germany, both the USA and Korea should be mentioned for large funding increases (120 % and 67 % respectively).

It is sometimes argued that funding derived from electricity bills (e.g. for many feed-in tariff schemes) is somehow different to that provided from consolidated revenue. However the view taken in this report is that a non-voluntary, government mandated levy on the electricity bill is simply another source of public funds that can be used to support PV.

Total public expenditure on PV RD&D and market stimulation in the IEA PVPS countries has now quadrupled compared to the late 1990's.
European Union R&D funding support for PV continued under the 6th RTD Framework Programme (FP6), which reached completion in 2006. Within the FP6, the European Commission provided a contribution of 104,8 MEUR in support of PV R&D. While they represent the interests of the EC rather than a summary of EU member countries' priorities, notable FP6 projects supported include: the CONCERTO initiative involving the demonstration of innovative PV systems, totalling 2,9 MW; the SISI and FOXY projects exploring alternative routes for solar grade silicon; CrystalClear, which has the goal of defining a manufacturing process for crystalline silicon to achieve a production cost of 1 EUR/W; the Lab2Line project which aims to take PV processes and materials successfully developed within previous research projects to manufacturing level; the ATHLET project, dealing with thin film technologies; HIGHSPEEDCIGS, which aims to demonstrate the economical production of CIGS solar cells; PV-ERA-NET, a four year initiative which aims to improve networking and integration of national and regional RTD programmes; and PV-CATAPULT with the goal of accelerating the development of PV towards market deployment. The 7th Framework Programme will operate from 2007 to 2013 and first calls for proposals were launched in December 2006. Work will include development and demonstration of new processes, standardized and tested building components, demonstration of additional benefits of PV electricity and longer term strategies for both high-efficiency and low-cost PV routes. The European PV Technology Platform, which comprises stakeholders from research, industry and government, developed in 2006 a Strategic Research Agenda that details R&D efforts needed over coming decades.

Whether at the national or multi-national level, continuing political support for PV is required, both for research and development, and for applications. Getting the balance right between R&D and market stimulation funding will be a challenge and will vary from country to country, but it is important for long-term market development. Cost and prices must continue to come down steadily for PV to maintain public favour and to grow the emerging interest from electricity utilities and investors.

Table 4 – Public budgets for R&D, demonstration / field trials and market stimulation in 2006

Country	R&D		Demonstration/ field trials		Market stimulation		Total	
	EUR	USD	EUR	USD	EUR	USD	EUR	USD
AUS	4,2 M	5,2 M	0,4 M	0,5 M	14,2 M	17,8 M	18,8 M	23,5 M
AUT	1,3 M	1,6 M	*included in R&D ammount*		*see notes below*		—	—
CAN	3,2 M	4,0 M	2,5 M	3,2 M	0,1 M	0,1 M	5,8 M	7,3 M
CHE	9,5 M	11,9 M	0,2 M	0,2 M	1,8 M	2,3 M	11,5 M	14,4 M
DNK	6,7 M	8,4 M	0,7 M	0,8 M	—	—	7,4 M	9,2 M
DEU	66,0 M	82,5 M	—	—	*see notes below*		—	—
FRA	26,2 M	32,8 M	—	—	20,0 M	25,0 M	46,2 M	57,8 M
GBR	10,6 M	13,3 M	11,6 M	14,5 M	—	—	22,2 M	27,8 M
ISR	0,1 M	0,1 M	—	—	—	—	0,1 M	0,1 M
ITA	4,8 M	6,0 M	0,2 M	0,3 M	6,0 M	7,5 M	11,0 M	13,8 M
JPN (METI)	21,8 M	27,2 M	93,5 M	116,9 M	28,5 M	35,7 M	143,8 M	179,8 M
KOR	15,8 M	19,7 M	0,2 M	0,3 M	81,3 M	101,6 M	97,3 M	121,6 M
MEX	0,8 M	1,0 M	0,7 M	0,9 M	—	—	1,5 M	1,9 M
NLD	9,4 M	11,7 M	—	—	3,0 M	3,8 M	12,4 M	15,5 M
NOR	1,7 M	2,1 M	—	—	—	—	1,7 M	2,1 M
SWE	1,5 M	1,9 M	—	—	0,7 M	0,9 M	2,2 M	2,8 M
USA	97,4 M	121,8 M	2,4 M	3,0 M	352,0 M	440,0 M	451,8 M	564,8 M

Notes: ISO country codes are outlined in Table 12.
Austria – The total amount of feed-in tariffs paid for PV in 2006 was approximately 8,7 MEUR.. Germany – The feed-in tariffs paid under the EEG are now so extensive that they are of the same order as all other amounts in the table added together (ie around the 1 billion USD mark). These are funded by the German electricity consumers.

2 The PV industry

This section provides information on the industry involved in the production of PV materials, cells, modules and system components during 2006. The industry may be subdivided into the following groups representing different steps in the PV supply chain:

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

A regional overview of PV cell and module manufacturing in the IEA PVPS countries during 2006 is presented in Table 5, which likely accounts for about 70 % to 75 % of the worldwide production, down from around 90 % the previous year due to the growth outside the IEA PVPS countries.

2.1 Feedstock, ingots and wafers (upstream products)

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

Feedstock

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

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

In 2006 there continued to be four major producers of solar photovoltaic grade silicon: Wacker in Germany, REC Solar Grade Silicon and Hemlock Semiconductor Corporation in the USA, and Tokuyama in Japan. Between them they produced about 60 % of the feedstock required by the PV industry in 2006. The balance was sourced from a handful of smaller companies, emerging producers outside the IEA PVPS countries (such as China and Russia) and remaining inventories and rejects from the semiconductor industry (recycled wafers, pot scrap, tops and tails etc). The USA is a large exporter at this level of the PV industry supply chain. It is reported that the selling price of solar photovoltaic grade silicon increased by about 20 % from 2005 to 2006.

The large companies have all announced significant expansion programmes. Some of these expansion projects will make use of new technologies, particularly the replacement of hot filament reactors (the so-called Siemens reactors) by fluidized bed reactors

Table 5 – PV cell and module production in 2006 by world region – IEA PVPS countries

		Japan	USA	Europe	Rest	Total
Cell Production	**All types, MW**	**920**	**201**	**730**	**54**	**1 905**
Cell Production Capacity	**MW / year**	***1 198***	***266***	***1 219***	***92***	***2 775***
Module Production	**sc-Si, MW**	135	57	106	–	**298**
	mc-Si, MW	456	51	232	52	**791**
	a-Si, MW	54	28	2	<1	**84**
	Undefined Si, MW	–	<1	405	20	**425**
	Other, MW	–	65	5	<1	**70**
	Total MW	**645**	**201**	**750**	**72**	**1 668**
Module Production Capacity	**MW / year**	***1 107***	***257***	***1 338***	***195***	***2 897***

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

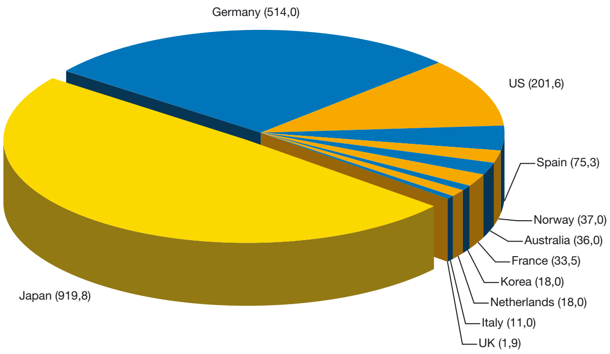

Figure 4 – PV cell production (MW) by country in 2006

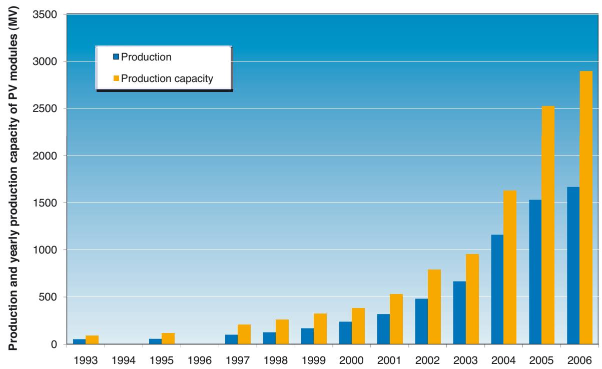

Figure 5 – PV module production and yearly module production capacity in the reporting countries (MW) between 1993 and 2006

for the deposition of silicon. Many newcomers have also announced plans to enter the feedstock silicon business. It is difficult to predict what may happen further along the industry supply chain as the current tight feedstock supply situation eases. Feedstock prices are fixed for a number of years and hedging contracts are in place – sudden drops in price should not be expected from these players. However order volumes should go up and consequently costs should go down.

Because of tightening of supply of low cost feedstock, R&D on new processes has seen a promising renaissance. Chemical companies are developing more cost efficient processes: fluidized bed reactors, free space reactors, vapour to liquid deposition, etc. Besides these developments through chemical processes, several companies are exploring the metallurgical route.

Ingots and wafers

Silicon ingots are of two types: single crystal and multicrystalline. The first type, although with different specifications regarding purity and specific dopants, is also produced for microelectronics applications, while multicrystalline ingots are only used in the PV industry. Ingot producers are in many cases also producers of wafers. European and Japanese companies feature most prominently in this section of the industry value chain.

Some companies are vertically-integrated, controlling the process from ingots to cells and modules. Under current tight feedstock market conditions, the companies having their own feedstock or having secured long term contracts are strategically poised to grow. An interesting trend is the decrease of wafer thickness, strongly motivated by the rising price of silicon feedstock and an ongoing focus on improving manufacturing efficiency.

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

2.2 Photovoltaic cell and module production

The total PV cell production volume for 2006 in the IEA PVPS countries was reported to be about 1 900 MW, up from 1 500 MW in 2005, an increase of 27 %. In reality, global growth is even stronger since production is also increasing rapidly outside the area covered by the reporting countries. The largest increases in production took place in Germany (additional 170 MW) and Japan (additional 96 MW).

Japan was the leading producer of photovoltaic cells (920 MW) and modules (645 MW) during 2006. Production of cells and modules in this country accounted for 48 % and 39 % respectively of the IEA PVPS countries' production, with Germany in second place with 27 % and 21 % of production respectively. The relative German market share in 2006 increased at the expense of the Japanese market share. The Japanese producer Sharp maintained its lead, with the German producer Q-Cells in second position, followed by Kyocera, Sanyo Electric and Mitsubishi Electric. These five companies accounted for about 60 % of total cell production in 2006. The four Japanese companies are also significant producers of modules. In the United States, the third largest producing country, production of cells increased by 29 % from 2005, while module production remained flat. However, US output of thin-film technologies saw another dramatic production increase of 94 %, on the back of a 109 % increase the previous year.

In 2006, photovoltaic module production in Europe clearly surpassed that of Japan for the first time. Crystalline silicon technologies maintained their dominance, accounting for 91 % of the market in the IEA PVPS countries. However, this percentage has

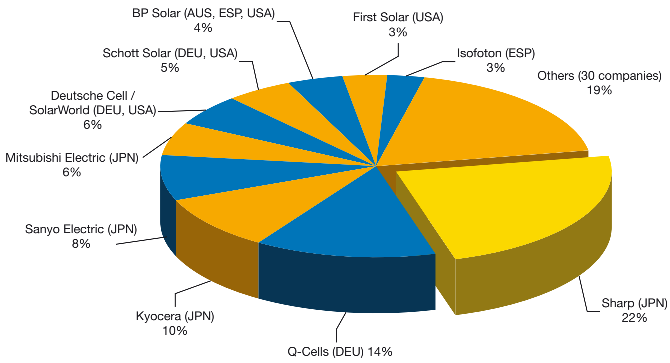

Figure 6 – Share of PV cell production in the reporting countries by company in 2006 (%)

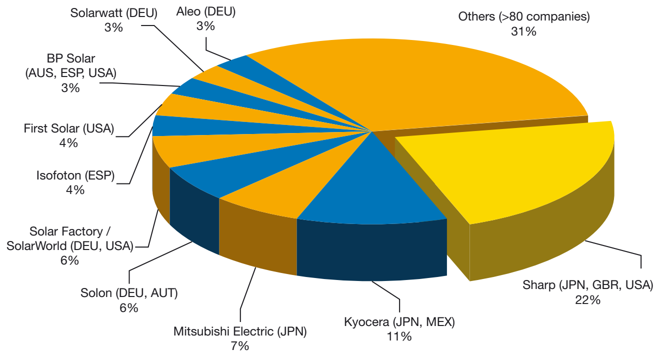

Figure 7 – Share of PV module production in the reporting countries by company in 2006 (%)

slipped three percentage points from the previous year. Interestingly, total 2006 module production only increased by about 9 % over 2005 production. Over the last decade in the IEA PVPS countries, each year's installed market growth expressed as a percentage of total module production has ranged from 65 % in 1998 to a high of 91 % in 2006.

The cell production capacity in the IEA PVPS countries, defined as the maximum output of manufacturing facilities, increased by 29 %, largely due to growth in Europe. Utilization of capacity was at 69 %, similar to the previous year and down from a high of 86 % in 2004. The increase in the module production capacity and the utilization of capacity were 15 % and 58 % respectively. It would appear that both production and investment for photovoltaic cells and modules in the IEA PVPS countries are responding to quite different drivers. In 2006, cells experienced both a production increase and investment in new facilities; module production was relatively flat and new investments were low. Module production is obviously closely linked to the market dynamics of the moment (with the two largest markets showing slower growth for 2006); the cell business possibly responds more strategically to longer-term expectations concerning the health of the whole PV supply chain.

2006 provided some interesting growth stories in individual countries and also at the global level. The reader is directed to the individual national reports for a comprehensive summary of manufacturers and production in each of the countries. Some consistent themes emerged from amongst the range of countries reporting during 2006, despite the variations of their policies and markets:

- cell supply problems are creating difficult circumstances for many smaller, disaggregated module producers
- foreign product and price offers are able to strongly impact domestic markets
- access to a booming foreign market can provide not only a lifeline but a goldmine for the industries in some countries where the domestic market has collapsed

IEA PVPS does not undertake direct assessments of production developments in countries not participating in the PVPS programme. However, analysis of other industry commentators' findings in relation to production in the rest of the world clearly demonstrates the rapidly growing importance of these other manufacturing centres. Photon International, for example, suggests that over 680 MW of cells and 700 MW of modules were manufactured outside of PVPS countries in 2006. Assuming this data to be correct, non-PVPS countries now account for over a quarter of global cell production and over 30 % of global module production. East Asia is the emerging powerhouse for PV cell and module production internationally, with China reportedly expanding cell production to over
380 MW in 2006, a rise of almost 140 % on 2005 which allowed it to leapfrog USA for the 3rd position on the annual national PV cell production tables. Taiwan accounted for a further 170 MW. Also noteworthy is the Philippines with close to 63 MW of cell production in 2006. Similarly, China accounts for the lion's share of non-PVPS module production, with an apparent production of over 510 MW in 2006. India (65 MW), Czech Republic (42 MW), South Africa (30 MW) and Thailand (20 MW) are also noteworthy module manufacturing countries. While the growth in production in non-PVPS countries has been impressive, there is still significant capacity to further increase output, with plant capacity utilization reportedly running at around 45 % for cell manufacturers and less than 40 % with respect to the module manufacturers.

Provided PV can retain the political favour it currently enjoys in a number of key markets for the next decade or so, continuing very high market growth rates of 30 % to 40 % per annum worldwide seem assured. This presents a very attractive proposition for investors of all kinds, as the increasing spate of public listings for PV companies attests. New, dedicated solar photovoltaic grade silicon investments will be coming on line over the next two years, which should bolster crystalline silicon's position as the mainstay material for PV cells for the foreseeable future and remove market growth constraints. At the same time, the recent and continuing constraint on cheap silicon is doing no damage to the prospects of thin-film technologies, as the elevation of First Solar to the top ten cell producers with its Cadmium telluride technology demonstrates. The global thirst for PV product is creating precisely the volume demand that will make 100+ MW to eventually GW scale production plants viable, the ideal environment for thin films to capture some of their long-promised market potential. A number of innovative thin-film technologies, including those based on nano-structures, are under investigation. However, the expectation is that these will not bring significant technology breakthroughs in the near term. Evolution, rather than revolution is the catch-cry for the present time. However, the steady march of the main manufacturing centres towards countries with lower production costs – notably East and South East Asia, but also central Europe – seems inevitable. This will accelerate PV electricity's convergence with the price of conventional electricity supplies, provided quality control is not compromised. Encouragingly the current dominant players in the new Asian manufacturing centres seem to be adopting international best practice for production and product quality.

2.3 Balance of system component manufacturers and suppliers

From a cost perspective, balance of system (BOS) components (the components that are not the PV modules) account for between 20 % (standard grid-connected system) and 70 % (off-grid installation) of the total PV system costs. Accordingly the production of BOS products has become an important sector within the wider PV industry. Particularly with the rapid expansion of the worldwide market for grid-connected PV systems, inverters are currently the focus of the interest. Following the further growth of the market for grid-connected PV, manufacturers of PV inverters for grid interconnection again experienced a considerable increase in their output during 2006.

In Europe the large manufacturing companies are located in Germany, Austria, Switzerland, Denmark and the Netherlands. In addition to the established companies, new activities have been reported from Spain and Italy, following the expansion of their national PV markets.

Outside Europe extensive activities in this field are reported from Japan, USA, Canada and Korea. It is likely that more than 40 companies are producing grid-connected inverters in these countries. The leading companies are based in Japan, Canada and USA. Today most of the products are dedicated to the residential PV market, with typical system sizes ranging from 2 kW up to 10 kW. However, with the increasing number of megawatt-scale systems being installed in some countries, inverters have been developed with capacities up to 1 MW. An important activity reported from Japan relates to the standardization of inverters of 10 kW and 100 kW, suitable for larger PV systems ranging up to 1 MW.

With new companies entering the market and the ongoing increase in production numbers, falling inverter prices were again reported in 2006. Prices quoted in the national reports range from 0,4 EUR/W up to 0,8 EUR/W. More companies are expanding their business into overseas markets, leading to increased competition and further reducing the prices for the products.

Tracking systems have recently become more attractive, particularly for PV applications in countries with a relatively high amount of direct solar radiation. It is expected that the energy yield of a tracking PV system can be increased by up to 40 % compared with non-tracking systems. Following this development, the number of companies offering trackers has been increasing. Activities concerning tracking systems have been reported from Australia, Austria and Spain.

Building integrated PV (BIPV) is the focus of a number of companies around the world, including the glass, façade construction and roofing materials industries. These companies are increasingly complementing their product range with new and innovative BIPV products.

In addition to basic BOS components, the production of specialized components, such as connectors, switchgear and monitoring systems has become an important business. Last but not least, the production of specialized equipment for the PV manufacturing industry is the focus of a number of companies. Products in this field 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 the production process.

2.4 System prices

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

Austria Module Production at Solon Hilber Technology AG, courtesy of fotoatelier, Steinach

Table 6 – Indicative installed system prices in selected countries in 2006

Country	Off-grid (per W)				Grid-connected (per W)			
	<1 kW		>1 kW		<10 kW		>10 kW	
	EUR	USD	EUR	USD	EUR	USD	EUR	USD
AUS	12–15	15–18,8	9	11,3	6–7,5	7,5–9,4	6	7,5
AUT	8–15*	10–18,8	8–15*	10–18,8	5–6	6,3–7,5	4,8–5,5	6–6,9
CAN	12,2	15,3			7	8,8	7	8,8
CHE	9,6–12,8	12–16	7,7–9,6	9,6–12	6,1–6,4	7,6–8	5,8	7,2
DNK	9,4–12,2	11,8–15,2	17,8–27	22,3–33,7	4,7–11,4	5,9–14,3	6,7–13,4	8,4–16,8
DEU					4,6–4,9	5,8–6,1	4,4	5,5
ESP	11,4–14,4	14,3–18	9,7–11,4	12,1–14,3	7–7,5	8,8–9,4	5,7–6	7,1–7,5
FRA	16,5	20,6	12	15	7,5	9,4	5	6,3
GBR	7,4–11,1	9,3–13,9	8,3–11	10,4–13,7	6,6–14,6	8,3–18,3	6,8–13,2	8,5–16,5
ISR	8–10,9	10–13,6	>8	>10				
ITA	11–14	13,8–17,5	11–13	13,8–16,3	6–6,8	7,5–8,5	5–6	6,3–7,5
JPN					4,7	5,8	5,2	6,4
KOR	16,8	21	15,1–16,8	18,9–21	5,9	7,4	4,9	6,1
MEX	10,9	13,6						
NLD	6,7	8,4			5,5	6,9	4,8	6
NOR	16,2–22,5	20,3–28,1			11,2–15	14–18,7		
SWE	10,9	13,6			6	7,5	5,4	6,8
USA	8–16	10–20	8–16	10–20	5,6–7,2	7–9	5,2–6	6,5–7,5

Notes: Additional information about the systems and prices reported for most countries can be found in the various national survey reports on the IEA PVPS website.
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. ISO country codes are outlined in Table 12

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

In 2006 the lowest system prices in the off-grid sector, irrespective of the type of application, ranged from about 9,5 USD to 15,0 USD per watt. The large range of reported prices is a function of country and project specific factors. The average of these system prices is about 12,5 USD per watt, slightly lower than the 13,0 USD per watt reported in 2005.

The lowest achievable installed price of grid-connected systems in 2006 also varied between countries as shown in Table 6. The average price of these systems was 6,8 USD per watt (compared with 6,5 USD and 6,6 USD per watt in 2004 and 2005 respectively). The lower reported prices in 2006 were typically around 6,0 USD to 6,5 USD per watt, also slightly higher than the prices reported for 2004 and 2005.

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

On average, the cost of the PV modules continues to account for about two-thirds of the lowest achievable prices that have been reported for grid-connected systems. While this is the case in most countries, there are a couple of examples (Denmark and Germany) where it appears that the nature of the programme in place or the market environment can result in lowest system prices close to the reported module prices. In 2006 the average price of modules in the reporting countries was around 4,6 USD/W, a marginal increase compared to the corresponding figure for 2005, which in itself represented a marginal increase from 2004. Table 7 shows the change in module (current) prices in some of the reporting countries from year to year. The breakdown of number of countries showing a marginal increase, no change and marginal decrease in module prices from 2005 to 2006 was roughly 50 %, 25 % and 25 % respectively.

In the period 2004 to 2006 the PV market size has approximately doubled. Learning curve theory suggests that the underlying cost (if not the market price) of modules in the IEA PVPS countries should have decreased by 15 to 20 % over this period.

Table 7 – Indicative module prices in national currencies (NC) per watt in selected reporting countries

Country	Currency	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006		
															NC	EUR	USD
AUS	AUD		7		8		8	8	8	8	7	7	8	8,0	7,5–9	4,5–5,4	5,6–6,8
AUT	EUR										4,5	3,1–3,2	3,6–3,7	3,6–3,9	3,6–4,3	3,6–4,3	4,5–5,4
CAN	CAD							11,09	10,7	9,41	7,14	6,18	5,53	4,31	5,36	3,8	4,7
CHE	CHF										7,5		4,1–4,3	4,5–4,7	5–5,2	3,2–3,4	4–4,2
DNK	DKK								40	40	33	21–45	30–50	30–50	40–60	5,4–8,1	6,7–10,1
DEU	EUR	5,93	5,42	4,91	4,50	4,14	3,73	3,63	3,58	3,53	3,04	2,5–9,7	3,0–9,6	4,0–6,0	4–5,3	4–5,3	5–6,6
ESP	EUR											2,6–4,25			3–4,5	3–4,5	3,8–5,6
FRA	EUR			13,3								4,2	4,0	4,2	3,2–5,1	3,2–5,1	4–6,4
GBR	GBP									4,24	4,24	2,3–4,0	2,4–3,8	2,4–4,3	2,5–3,9	3,7–5,8	4,6–7,2
ISR	USD											5–6,3	4,5–6,1	5,4	5,4	4,3	5,4
ITA	EUR	4,65				4,13				3,9–4,7	3,5–4,3	3,1–3,9	3,0–3,6	3,2–4,0	3,2–3,6	3,2–3,6	4–4,5
JPN	JPY	950	927	764	646	652	652	598	542	481	463	451	441	428	433	3	3,7
KOR	KRW		9 400	9 400	8 200	8 500	9 200	7 500	7 100	7 200	7 200	7 000	4 600	4 600	4 400	3,7	4,6
MEX	MXP											65	68–80	73–85	74,5–88	5,4–6,5	6,8–8,1
NLD	EUR		9,5	7	7,5	6	5	4,75	4,73	4,73	4,62	4,5	3,5–4,5	3,8–5,0	3,3–4,5	3,3–4,5	4,1–5,6
SWE	SEK											26–70	26–70	32–70	30–65	3,3–7	4,1–8,8
USA	USD	4,25	4,00	3,75	4,00	4,15	4,00	3,50	3,75	3,50	3,25	3,0	3,5	3,6	3,75	3	3,75

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

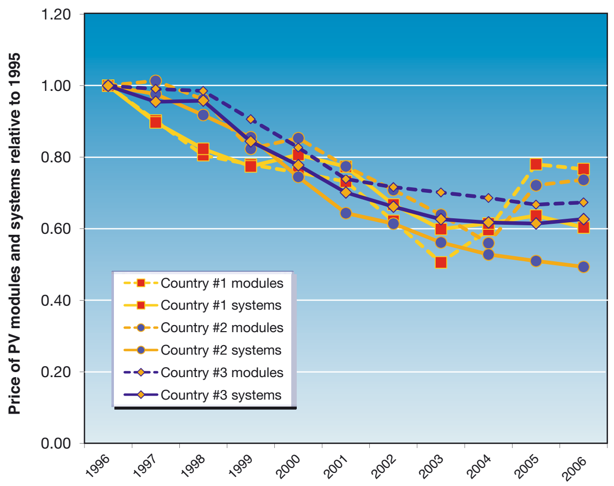

Figure 8 – Evolution of price of PV modules and systems in selected reporting countries accounting for inflation effects – Years 1996–2006 (Normalized to 1996)

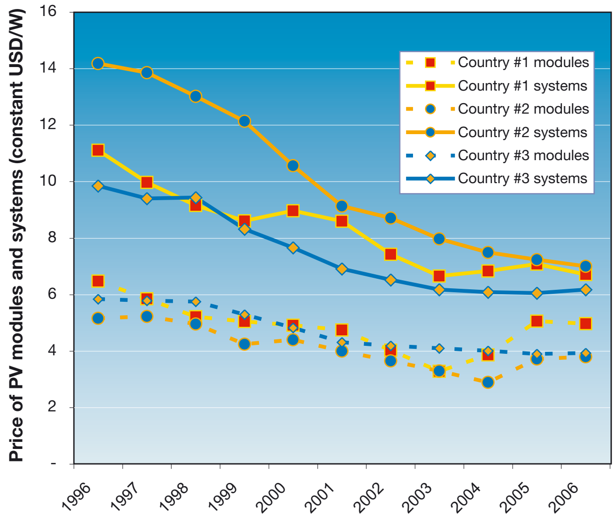

Figure 9 – Evolution of price of PV modules and systems in selected reporting countries accounting for inflation effects – Years 1996–2006

Besides the effects on costs and prices caused by the dynamics of market demand, tight solar photovoltaic grade silicon feedstock supply and development and competition in the industry, it is worth noting that 70 % of the production costs for a PV module are due to the materials required, including such things as aluminium, copper and other minerals. It appears that there are many companies that have not secured 100 % of needed raw materials, which they must then buy on the open market.

Figure 8 and Figure 9 show the evolution of normalized and actual prices respectively for modules and systems, accounting for inflation effects, in selected key markets. It is interesting to note that, over a decade, system prices have decreased by probably more than 40 % while module prices have decreased by less than 30 %.

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 10). This is highlighted by the variety of business models across the IEA PVPS countries. Business value calculations can be found in each national report.

Significant value of business has been reported by countries with healthy domestic PV market growth and/or large export of production from somewhere along the PV industry supply chain. Over half of the reporting countries can be regarded as significant exporters – and about half of these are reporting negligible annual markets. In absolute terms Germany is both a significant importer and exporter. Japanese exports are large (for example, over 600 MW of PV cells) but are facing rapidly mounting competition, not least from outside the IEA PVPS countries. Norway reports a high value of business because of its position as a major upstream product supplier. The total value of business in 2006 amongst the IEA PVPS countries was approximately 10 billion USD.

In parallel with the business value of PV production and markets, the economic value in the IEA PVPS countries can be characterized by the total direct employment of about 70 000 persons across research, manufacturing, development and installation – an increase of close to 30 % compared to 2005. Many manufacturing companies in Europe have continued to benefit from the strong level of demand within Germany, even when their domestic markets have diminished. In addition, new programmes have emerged in a number of countries – notably in Spain, Korea, Italy, the USA and France.

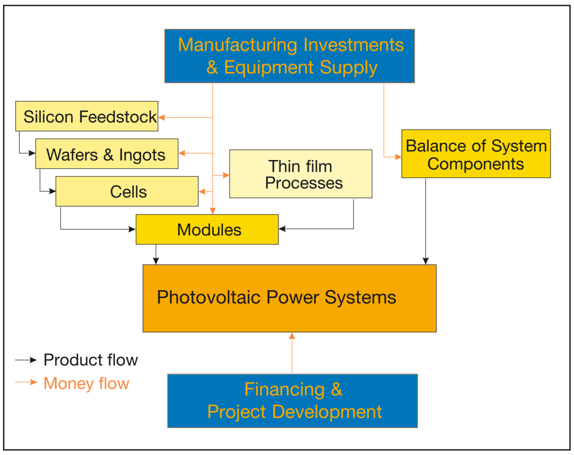

Figure 10 – PV industry supply chain

3 Policy and regulatory framework for deployment

Local, national and international policies, as well as availability of suitable standards and codes and the perception of the general public and utilities, govern the rate of deployment of PV systems.

3.1 New initiatives supporting photovoltaic power systems

An outline of the range of PV support mechanisms in place in the IEA PVPS countries during 2006 – and in some cases up to the time of writing in 2007 – can be found in Table 8. Some countries rely on a smaller number of clearly targeted approaches; others employ a broader combination of measures. Some of these reported measures are applied at the national level while others are only local or regional schemes. Details about many of these measures can be found in section 1.3 of this report and further details are available in the relevant national reports.

The main fiscal instruments being used to publicly support or promote PV in the IEA PVPS countries continue to be the enhanced feed-in tariffs, with direct capital subsidies also playing an important role. In practice, public support can involve a combination of measures and will usually function more effectively when this is the case. Funding issues are significant and are critical to the success of any mechanism.

The growing popularity of the feed-in tariff (FiT) approach for grid-connected PV is clear. However, while a high tariff level has been shown to be capable of driving substantial market growth, some of the controlling conditions that have been placed on different countries' schemes have resulted in difficulties in achieving such a result or sustaining high levels of investment. These controlling conditions have included caps on PV capacity allowed under the scheme, exclusion of certain types of projects such as BiPV or large-scale plants (or lack of appropriate differentiation of tariffs), inadequate period guaranteed for the FiT and overly complex administrative requirements. Even in Germany, where these problems have largely been avoided, the combination

Table 8 – PV support mechanisms reported by participating countries

	AUS	AUT	CAN	CHE	DNK	DEU	ESP	FRA	GBR	ISR	ITA	JPN	KOR	MEX	NLD	NOR	SWE	USA
Enhanced feed-in tariffs		•	•	•		•	•	•		•	•		•					•
Direct capital subsidies	•	•		•	•	•		•	•			•	•		•		•	
Green electricity schemes	•	•	•	•		•			•	•		•			•			•
PV-specific green electricity schemes	•	•		•	•				•									•
Renewable portfolio standards (RPS)	•								•			•					•	•
PV requirement in RPS																		•
Investment funds for PV			•			•	•								•			•
Tax credits			•	•				•	•			•			•		•	•
Net metering	•	•	•	•	•				•		•				•			•
Net billing	•		•	•					•			•						
Commercial bank activities	•					•						•						•
Electricity utility activities	•		•	•	•	•			•			•	•		•			•
Sustainable building requirements	•		•	•			•						•		•			•

of a generous FiT and a year-by-year decrease in the tariff level has driven a huge demand very quickly, which has created its own challenges – sustaining the required level of investor interest may be difficult when system prices do not also fall steadily.

The FiT mechanism does not lend itself to ready prediction of outcomes where, for example, a certain amount of PV electricity or rates of deployment are being sought. If the pool of potential investors is not adequately understood – their motivations, financial positions and so on – overheated markets can result if the tariffs are set too high. Set the tariffs too low and the investments could be negligible, consequently wasting the time and effort that has been invested in development of the scheme. It is less disruptive of developing markets to increase tariffs if set too low, than to decrease them at a rate faster than originally published, if set too high. However this, and the need for setting the problematic cap on the size of the scheme, can be overcome by more clearly targeting the approach on specific, limited market segments, which can then be expanded over time.

Direct capital subsidies can effectively tackle the up-front cost barrier, which is often the most significant hurdle facing PV deployment, and can be used in both the grid-connected and off-grid markets. They can be very effective (as the Japanese residential PV market has demonstrated) and are relatively simple to implement. Criticisms include: they do not drive PV system performance (although schemes are now emerging where performance is considered); they do not encourage broader consideration of customer energy usage (unless this is specifically addressed, for example through metering displays such as in the Danish SOL programmes); and they do not address the customer's willingness to pay for PV (unless a bidding mechanism is used, such as in Malaysia's SURIA 1000 Programme). Direct capital subsidies are also more broadly criticized for inflating prices and subsidizing more affluent consumers.

Similar to the direct capital subsidies, tax credits can, to a degree, tackle the up-front cost barrier and various forms of this measure have emerged in a number of countries. However, it assumes that entities with a tax liability are prime candidates for PV, which may or may not be the case depending on the particular market. Further, while more economically efficient, it is probably not as effective in the early stages of PV market development when deployment targeted on specific end-users may produce the best results.

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

3.2 Indirect policy issues and their effect on the PV market

Two main policy issues are focusing the attention of many governments on the potential and role of renewable energy in their energy supply mix – climate change has recently assumed a much higher profile, and both local and global energy security issues continue to make an impact. As a consequence many governments are implementing or strongly debating the regulatory approach commonly referred to as the 'renewable portfolio standard' (RPS) to increase renewable energy deployment in their countries. However, in the absence of at least some concrete targets for installed capacity of PV, the RPS is unlikely to have a positive impact on PV deployment as the general requirement for renewable energy may simply encourage the lowest direct cost renewable energy options (and not PV) for consideration.

However, in the USA in particular, a number of PV-specific regulatory approaches have emerged. Notable amongst these state-based initiatives are the Arizona Environmental Portfolio Standard, the Colorado Renewable Energy Standard, New Jersey's requirements, the PV 'set-asides' of Pennsylvania and the District of Columbia, and New Mexico, Nevada, Maryland and Delaware where additional credits are provided for energy provided by PV systems. Details about these programmes can be found at www.dsireusa.org.

In addition, driven largely by the current round of climate change politics, sustainable building regulations are an emerging force in many countries. These include requirements on new building developments (residential and commercial) and also in some cases on properties for sale. The implications for PV deployment may be modest where, for example, PV is included in a suite of options for reducing the building's energy foot print, or dramatic as is the case in Spain where PV is specifically mandated as an inclusion in the building development.

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

Within the electricity utility sector, different business models of PV promotion are emerging, partly in response to public policy and regulation and partly to realize business opportunities. There are a number of 'green power' schemes offered by electricity businesses, in which customers can purchase green electricity. In principle, these rely on part of the customer base giving some environmental or other value to renewable energy – and paying a premium for the privilege. Electricity businesses also have an opportunity to maximize network benefits and promote other benefits when they support or invest in projects that will form part of their green power scheme. However green power schemes are often characterized by the same problems for PV seen in the government-driven RPS approaches – they are usually characterized by a broad, least-cost approach favouring hydro, wind and biomass.

As with the RPS approach, a number of PV-specific approaches have emerged – partly in response to a particular utility's approach to its customers and PV, and partly as a function of market diversity and competitive pressures. Denmark's Copenhagen Electric sells certified PV electricity, with the scheme reporting small but growing success even though the end-user cost of the certified PV electricity is three to four times that of standard electricity. In the United States a number of utilities are offering their customers the opportunity to purchase PV electricity specifically. In Australia, electricity utility Origin Energy (also a PV manufacturer) offers 'GreenEarth Solar', a 100 % PV electricity green power product. The Swiss solar stock exchanges, in which PV power is produced and sold to individuals and institutions interested in purchasing clean electricity, have proved to be a mainstay in the promotion of PV in Switzerland. Japanese electricity utilities introduced the 'Green Power Fund' based on contributions from supporting customers. During financial year 2006 149 PV projects totaling 2 162 kW in total were developed as part of this fund.

3.3 *Standards and codes*

Established in 1981, the Technical Committee (TC) 82 of the International Electrotechnical Commission (IEC, www.iec.ch) has been the main promoter of world wide standardization in the field of PV. As of the end of 2006, 42 IEC International Standards and Technical Specifications had been published covering a comprehensive range of issues. In 2006 two new countries became full members and currently 25 countries are active participants in TC 82 and a further 12 have observer status.

The work on new and revised standards is carried out within six individual working groups (WG) consisting of experts dealing with issues ranging from Glossary to Balance-of-system components. Further cross-cutting issues such as Rural Electrification or Batteries are handled by a Joint Working & Coordination Group (JWCG) of experts from different TCs. Conformity assessment and certifications are treated within the framework of the IECEE (Worldwide System for Conformity Testing and Certification of Electrical Equipment).

TC 82 has been very active during 2006 and has published the following new or revised IEC standards or Technical Specifications (TS)

- Photovoltaic devices – Part 1: Measurement of photovoltaic current-voltage characteristics (IEC 60904-1 2006-09)
- Recommendations for small renewable energy and hybrid systems for rural electrification – Part 7-1: Generators – Photovoltaic arrays (IEC/TS 62257-7-1 2006-12)
- Part 9-2: Microgrids (IEC/TS 62257-9-2 2006-10)
- Part 9-3: Integrated system – User interface (IEC/TS 62257-9-3 2006-10)
- Part 9-4: Integrated system – User installation (IEC/TS 62257-9-4 2006-10)

Continuing the activities from the previous year, revisions to the IEC 60904-X series, which define fundamental requirements such as measurement principles for photovoltaic devices, have been at the top of TC 82's agenda. In 2006, one revised document (IEC 60904-1) has been published. Further important work items currently on TC 82's list include power and energy rating of PV modules and on-site measurements of PV array I/V characteristics. New activities and proposed work covers issues regarding the traceability of PV reference sensors, directly coupled PV pumping systems and portable solar lanterns. In the field of BOS, WG6 is developing a new project on BOS performance, which will include requirements and methods for assessment of the performance of BOS components, particularly inverters and charge controllers.

On the European level the CLC/TC 82 of the European Committee for Electrotechnical Standardization (CENELEC) supports the PV market by harmonization of standards. In this context CLC/TC 82 closely cooperates with its counterpart, the IEC TC 82 as well as the national committees. In areas where there is special European concern, CLC/TC 82 is also developing its own standards. In 2006, one new European Standard (EN) has been published by the CLC on Solar cells – Datasheet information and product data for crystalline silicon solar cells (EN 50461:2006). New or recent projects topping

Table 9 – Characteristics of some key support measures

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

CLC/TC 82's agenda deal with connectors for photovoltaic systems, data sheet information for grid-connected PV inverters and performance of grid-connected inverters for PV systems.

In the US standardization focuses on safety and interconnection issues of PV systems. In the framework of the US DOE National Photovoltaic program a critical portion of the standards, codes and certification activities are supported and funded. The support and leadership has provided a consensus of utility and industry input into the National Electrical Code® (NEC®), new and revised listing standards for safety, utility interconnect standards, standards input into the international arena and hardware certification. US representatives also actively participate in the IEC TC 82.

In Japan, the Japanese Standards Association and the Japan Electrical Safety and Environment Technology Laboratories (JET) are very active in the field of PV standardization. In 2006, five new Japanese Industrial Standards (JIS) or TS were published. Most of them are consistent with the IEC documents. Further, discussions are currently underway for nine documents covering issues from general rules for PV arrays and stand-alone systems, lifetime of PV modules, performance measurement for PV systems and PV components. JET is running large-scale certification programmes for PV modules as well as inverters that are also constantly amended to cover latest developments.

Grid connection of PV systems still remains a critical issue. However, new developments and national activities reported by some countries indicate that there is strong support for a smooth and easy grid connection of PV systems to the electricity distribution networks. A number of countries also reported on new or amended guidelines dealing with design, installation and operation of PV installations, aiming at reducing barriers and simplifying the deployment of PV.

PV GAP, the PV Global Approval Programme aims to promote globally accepted standards, testing laboratories and reference manuals for PV manufacturers with a focus on developing countries. Based on the IECEE certification scheme, a "PV Quality Mark" for PV components and a "PV Quality Seal" for PV systems are licensed to manufacturers if their product qualifies according to the requirements. By the end of 2006, six companies had achieved the PV GAP label licensing.

40 kW PV plant, Narni, Italia (courtesy of GSE)

4 Summary of trends

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

- 2006 provided a number of interesting stories regarding installed PV power in the IEA PVPS reporting countries. The market for PV power applications continued to expand in a healthy fashion: between 2005 and 2006 the cumulative installed capacity in the IEA PVPS countries grew by 36 % reaching 5,7 GW, with over 1,5 GW added during 2006. As in recent years, by far the greatest proportion in 2006 was installed in Japan and Germany alone (82 %). At the same time, the market for PV modules (annual sales volume) in both Germany and Japan in 2006 was broadly similar to 2005.

- Grid-connected applications dominated in the reporting countries (about 96 % of the 2006 market), but with roughly one third of countries reporting off-grid applications as their dominant market.

- 2006 saw a large increase in total public budgets compared to 2005, to over 2 billion USD. While this was largely due to the increasing amounts being paid under market stimulation measures, expenditure on RD&D also increased by about 17 %. Nearly all countries reported increases in total expenditure for 2006 compared to 2005.

- In 2006 there continued to be four major producers of solar photovoltaic grade silicon and between them they produced about 60 % of the feedstock required by the PV industry in 2006. The balance was sourced from a handful of smaller companies, emerging producers outside the IEA PVPS countries and remaining inventories and rejects from the semiconductor industry.

- European and Japanese companies feature most prominently in the ingot and wafer section of the industry supply chain for crystalline silicon products. Some companies are vertically-integrated, controlling the process from ingots to cells and modules. The companies having their own feedstock or having secured long term contracts are those best able to grow. An interesting trend, as manufacturers search for more effective materials' utilization, is the decrease of wafer thickness.

- The total photovoltaic cell production volume for 2006 in the IEA PVPS countries was reported to be about 1 900 MW, an increase of 27 % from 2005. The largest growth in absolute numbers took place in Germany (170 MW) and Japan (96 MW). Japan was the leading producer of cells (920 MW) and modules (645 MW) during 2006. Production of cells and modules in this country accounted for 48 % and 39 % respectively of the IEA PVPS countries' production, with Germany in second place with 27 % and 21 % of production respectively. The relative German market share in 2006 increased at the expense of the Japanese market share.

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

Year	Cumulative installed power and percentage increase						Power installed during year in IEA PVPS reporting countries (MW)	Module production during year in IEA PVPS reporting countries (MW)
	Off-grid		Grid-connected		Total			
	MW	%	MW	%	MW	%		
1992	78		32		110			
1993	94	21	42	32	136	24	26	52
1994	112	19	52	24	164	20	28	
1995	132	18	67	29	199	21	35	56
1996	158	19	87	32	245	23	46	
1997	187	19	127	46	314	28	69	100
1998	216	15	180	42	396	26	82	126
1999	244	13	276	54	520	31	124	169
2000	277	14	452	64	729	40	206	238
2001	319	15	670	48	989	36	260	319
2002	354	11	980	46	1 334	35	345	482
2003	410	16	1 418	45	1 828	37	494	667
2004	452	10	2 406	70	2 858	56	1 030	1 160
2005	*512*	*13*	*3 668*	*52*	*4 180*	46	1 322	1 532
2006	*575*	*12*	*5 120*	*40*	*5 695*	**36**	**1 515**	**1 668**

Notes: 2004, 2005, 2006 figures no longer include Finland. ***2006 total (MW) and power installed during year (MW) include estimate for Portugal;*** *2006 off-grid (MW) and (%) and grid-connected (MW) and (%) do not include Portugal.*

- In 2006 module production in Europe clearly surpassed that of Japan for the first time. Crystalline silicon technologies maintained their dominance, accounting for 91 % of the market. However, this percentage has slipped three percentage points from the previous year with the further emergence of thin films. Interestingly, total module production in IEA PVPS countries in 2006 only increased by about 9 % over 2005 production.

- Non – IEA PVPS countries (particularly China, Taiwan, India, and the Philippines) now possibly account for over a quarter of global cell production and over 30 % of global module production.

- Some consistent themes emerged during 2006: PV cell supply problems are creating difficult circumstances for many smaller, disaggregated module producers; foreign product and price offers are able to strongly impact domestic markets; access to a booming foreign market can provide significant opportunities for the industries in some countries where the domestic market has collapsed; and East Asia is the emerging powerhouse for PV cell and module production internationally.

- On average, PV modules continued to make up about two-thirds of the lowest achievable grid-connected system prices that have been reported. In 2006 the average price of modules in the reporting countries was around 4,6 USD/W, a marginal increase compared to the corresponding figure for 2005, which in itself represented a marginal increase from 2004.

- The average price of grid-connected PV systems in 2006 was 6,8 USD per watt compared with 6,5 USD and 6,6 USD per watt in 2004 and 2005 respectively. The lower reported prices in 2006 were typically around 6,0 USD to 6,5 USD per watt, also slightly higher than the prices reported for 2004 and 2005. On average, system prices for the lowest price off-grid applications are double those for the lowest price grid-connected applications.

- The total value of business in 2006 amongst the IEA PVPS countries was approximately 10 billion USD. In parallel with the business value of PV production and markets, the economic value in the IEA PVPS countries can be characterized by the total direct employment of about 70 000 persons across research, manufacturing, development and installation.

Table 11 – IEA PVPS Task 1 national report authors

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- The main fiscal instruments being used to publicly support or promote PV in the IEA PVPS countries continue to be the enhanced feed-in tariffs, with direct capital subsidies also playing an important role. Tax credits for PV deployment have emerged in a number of countries. Two main policy issues are focusing the attention of many governments on the potential and role of renewable energy in their energy supply mix – climate change has recently assumed a much higher profile, and both local and global energy security issues continue to make an impact.

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Exchange rates

Table 12 lists the participating countries, corresponding ISO country and currency codes, and the exchange rates used to convert national currencies. Exchange rates represent the 2006 annual average of daily rates (source: OECD Main Economic Indicators June 2007).

Table 12 – Exchange rates

Country	ISO country code	Currency and code	Exchange rate (1 USD =)
Australia	*AUS*	*Dollar (AUD)*	*1,33*
Austria	*AUT*	*Euro (EUR)*	*0,80*
Canada	*CAN*	*Dollar (CAD)*	*1,13*
Denmark	*DNK*	*Krone (DKK)*	*5,94*
France	*FRA*	*Euro (EUR)*	*0,80*
Germany	*DEU*	*Euro (EUR)*	*0,80*
Israel	*ISR*	*Dollar (USD)*	*1,00*
Italy	*ITA*	*Euro (EUR)*	*0,80*
Japan	*JPN*	*Yen (JPY)*	*116,35*
Korea	*KOR*	*Won (KRW)*	*951,82*
Mexico	*MEX*	*Peso (MXP)*	*10,90*
Netherlands	*NLD*	*Euro (EUR)*	*0,80*
Norway	*NOR*	*Krone (NOK)*	*6,41*
Portugal	*PRT*	*Euro (EUR)*	*0,80*
Spain	*ESP*	*Euro (EUR)*	*0,80*
Sweden	*SWE*	*Krona (SEK)*	*7,37*
Switzerland	*CHE*	*Franc (CHF)*	*1,25*
United Kingdom	*GBR*	*Sterling (GBP)*	*0,54*
United States	*USA*	*Dollar (USD)*	*1,00*

PV Technology Note

*The key components of a photovoltaic power system are the **photovoltaic cells** (sometimes also called solar cells) interconnected and encapsulated to form a **photovoltaic module** (the commercial product), the **mounting structure** for the module or array, the **inverter** (essential for grid-connected systems and required for most off-grid systems), the **storage battery** and **charge controller** (for off-grid systems only).*

Cells, modules and arrays

Photovoltaic cells represent the smallest unit in a photovoltaic power producing system, typically available in 12,5 cm, 15 cm up to 20 cm square sizes (crystalline type). In general, cells can be classified as either *crystalline* (*single crystal* or *multicrystalline*) or *thin film*. At present, the vast majority of photovoltaic cells are made from silicon (crystalline silicon wafer or thin film hydrogenated amorphous silicon).
Currently crystalline silicon technologies account for most of the overall cell production in the PVPS countries.
Single crystal silicon PV cells are manufactured using a single crystal growth method and have commercial efficiencies between 16 % and 18 %.
Multicrystalline silicon cells, usually manufactured from a melting and solidification process, are less expensive to produce but are marginally less efficient, with an average efficiency between 14 % and 15 %. PV cells made from ribbons show an average efficiency around 14 %.
Thin film cells are constructed by depositing extremely thin layers of photovoltaic semi-conductor materials onto a backing material such as glass, stainless steel or plastic. Thin film materials commercially used are hydrogenated amorphous silicon (a-Si), cadmium telluride (CdTe), and copper-indium-gallium-diselenide (CIGS). Commercially available thin film modules show stable efficiencies in the range of 6 % to 11 %, (*figure reported in 2005*) but they are potentially cheaper to manufacture than crystalline cells. They have a wider customer appeal as design elements due to their homogeneous appearance. The disadvantage of low conversion efficiencies is that larger areas of PV arrays and more material (cables, support structures) are required to produce the same amount of electricity.
Further research and development is being carried out to improve the efficiency of all the basic types of cells with laboratory efficiencies for *single crystal* cells over 25 %, and for thin film technologies over 19 % being achieved.

Photovoltaic modules are typically rated between 50 W and 200 W but several manufacturers now offer modules up to 300 W with specialized products for building integrated PV systems at even larger sizes. Crystalline silicon modules consist of individual PV cells connected together and encapsulated between a transparent front, usually glass, and a backing material, usually plastic or glass. Thin film modules are constructed from single sheets of thin film material and can be encapsulated in the form of a flexible or fixed module, with transparent plastic or glass as front material. Quality PV modules are typically guaranteed for up to 20 years by manufacturers and are type approved to IEC 61215 or IEC 61646 International Standards.
Most complete systems consist of a number of modules connected together in the form of a PV array to give a higher power rating.

A **PV array** consists of a number of modules connected in series (strings), then coupled in parallel to produce the required output power.
A wide range of **mounting structures** has been developed especially for building integrated PV systems (BIPV), including PV facades, sloped and flat roof mountings, integrated (opaque or semi-transparent) glass-glass modules and 'PV roof tiles'.

Grid-connected PV systems

In grid-connected PV-systems, an **inverter** is used to convert electricity from direct current (d.c.) as produced by the PV array to alternating current (a.c.) that is then supplied to the electricity network. The typical weighted conversion efficiency – often stated as 'European Efficiency' – of inverters is in the range of 94 %, with peak efficiencies up to 97 %. Inverters connected directly to the PV array incorporate a Maximum Power Point Tracker (MPPT), which continuously adjusts the load impedance to provide the maximum power from the PV array. One inverter can be used for the whole array or separate inverters may be used for each 'string' of modules. PV modules with integrated inverters, usually referred to as 'AC modules', can be directly connected to the electricity network (where approved by network operators) but still play a minor role.

Off-grid PV systems

For off-grid systems a **storage battery** is required to provide energy during low-light periods. Nearly all batteries used for PV systems are of the deep discharge lead-acid type. Other types of batteries (e.g. NiCd, NiMH) are also suitable and offer some advantages, but are considerably more expensive. The lifetime of a battery varies depending on the operating regime and conditions but is typically between 5 and 10 years.
A **charge controller** (or regulator) is used to maintain the battery at the highest possible state of charge (SOC) and provide the user with the required quantity of electricity while protecting the battery from deep discharge or overcharging. Some charge controllers also have integrated MPP trackers to maximize the PV electricity generated.
If there is the requirement for a.c. electricity, a **'stand-alone inverter'** can supply conventional a.c. appliances.

Further details

More detailed descriptions of PV technology and applications can be found on the IEA PVPS website at www.iea-pvps.org .

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