IEA INTERNATIONAL ENERGY AGENCY

TRENDS 2017

IN PHOTOVOLTAIC APPLICATIONS

22ND EDITION 2017

Survey Report of Selected IEA Countries between 1992 and 2016

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

PVPS

Report IEA PVPS T1-32:2017

COVER IMAGE
Pope Paul VI Audience Hall, viewed from the dome of St. Peter's, showing the photovoltaic panel roof © nomadFra/shutterstock

REPORT SCOPE AND OBJECTIVE

Annual surveys of photovoltaic (PV) power applications and markets are carried out in the reporting countries, as part of the IEA PVPS Programme's work.

The Trends reports objective is to present and interpret developments in the PV power systems market and the evolving applications for these products within this market. These trends are analysed in the context of the business, policy and nontechnical environment in the reporting countries.

This report is prepared to assist those who are responsible for developing the strategies of businesses and public authorities, and to support 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. National data supplied are as accurate as possible at the time of publication. Data accuracy on production levels and system prices varies, depending on the willingness of the relevant national PV industry to provide data. This report presents the results of the 22nd international survey. It provides an overview of PV power systems applications, markets and production in the reporting countries and elsewhere at the end of 2016 and analyses trends in the implementation of PV power systems between 1992 and 2016. Key data for this publication were drawn mostly from national survey reports and information summaries, which were supplied by representatives from each of the reporting countries. These national survey reports can be found on the IEA PVPS 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, the validity of some of these data cannot be assured with the same level of confidence as for IEA PVPS member countries.

DISCLAIMER

Numbers provided in this report, "Trends 2017 in Photovoltaic Applications", are valid at the time of publication. Please note that all figures have been rounded.

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FOREWORD

The IEA PVPS Programme is proud to provide you its 22nd edition of the international survey report on Trends in Photovoltaic (PV) Applications.

Tracking the global progress in PV markets and industry systematically since 1992, the "Trends Report" is one of the flagship publications of the IEA PVPS Programme and an important source of unbiased and objective information. The unique series of "Trends Reports" has covered the transition of PV technology from its early and expensive niche market developments in the 1990s to the recent large-scale global deployment and increased competitiveness. 2016 was a record year which saw the PV market jumping to 76 GW for the very first time. It has confirmed the global PV markets trends and the consolidated market development observed since 2013. The rise of PV markets in Asia and Americas has been confirmed, with China installing more than 34 GW alone. Overall, more than 65 GW of PV were installed in the IEA PVPS member countries during 2016, whereas the global PV market is estimated to stand just below 76 GW. The global installed total PV capacity is estimated at roughly 303 GW at the end of 2016 and will have reached close to 400 GW at the end of 2017. PV modules and system prices have seen again a significant decline, pushed by industry overcapacities but also extremely competitive tenders on all continents. On the industry supply side, production increased again whereas competition remains high. Policy support continues to be relevant but is quickly moving towards new more market-oriented business models, even if feed-in tariffs and similar financial incentives remain the main driving force. In many regions of the world, PV is becoming the cheapest option for electricity generation from not only new renewable energy technologies but also all conventional technologies. With bids close to 20 USD/kWh, PV has the potential to become the cheapest source of power generation everywhere in the coming years. All of these developments are accompanied by continuous technology evolution, making PV a growing player in the energy field. With its rising level of penetration within electric grids, PV is more and more affecting electricity systems as a whole and the integration into various technical and economic environments becomes crucial. Quantitatively, the number of countries experiencing PV as an essential part of their electricity supply is increasing, with more than 30 countries covering more than 1% of their electricity supply from PV, and PV has in sight a share of 2% of the global electricity supply. Altogether, these are encouraging signs of a maturing industry which is however only at the early beginning of its future market relevance, with many developments expected in the building and transport sector. Learn all about the details of this exciting development by reading through our 22nd edition of the Trends Report!

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PV TECHNOLOGY AND APPLICATIONS

PV TECHNOLOGY

Photovoltaic (PV) devices convert light directly into electricity and should not be confused with other solar technologies such as concentrated solar power (CSP) or solar thermal for heating and cooling. The key components of a PV power system are various types of photovoltaic cells (often 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 but also increasingly for grid-connected ones).

CELLS, MODULES AND SYSTEMS

Photovoltaic cells represent the smallest unit in a photovoltaic power producing device, typically available in 12,5 cm and 15,6 cm square sizes. In general, cells can be classified as either wafer-based crystalline (single crystal and multicrystalline silicon), compound semiconductor (Thin-film), or organic. Currently, crystalline silicon technologies account for more than 90% of the overall cell production and more than 94% in the IEA PVPS countries. Single crystal silicon (sc-Si) PV cells are formed with the wafers manufactured using a single crystal growth method and have commercial efficiencies between 16% and 25%. Multicrystalline silicon (mc-Si) cells, usually formed with multicrystalline wafers manufactured from a cast solidification process, have remained popular as they are less expensive to produce but are less efficient, with average conversion efficiency around 14-18%. III-V compound semiconductor PV cells are formed using materials such as GaAs on the Ge substrates and have high conversion efficiencies of 40% and more. Due to their high cost, they are typically used in concentrator PV (CPV) systems with tracking systems or for space applications. Thin-film cells are formed by depositing extremely thin layers of photovoltaic semiconductor materials onto a backing material such as glass, stainless steel or plastic. Thin-film modules used to have lower conversion efficiencies than basic crystalline silicon technologies but this has changed in recent years. They are potentially less expensive to manufacture than crystalline cells. Thin-film materials commercially used are cadmium telluride (CdTe), and copper-indium-(gallium)-diselenide (CIGS and CIS). Amorphous and micromorph silicon (a-Si) used to have a significant market share but failed to follow both the price of crystalline silicon cells and the efficiency increase of other thin film technologies. In terms of efficiencies, CdTe cells reached in 2016 22% in labs. Organic thin-film PV cells, using dye or organic semiconductors, have created interest and research, development and demonstration activities are underway. In recent years, perovskites solar cells have reached efficiencies higher than 22% in labs but have not yet resulted in stable market products.

Photovoltaic modules are typically rated between 40 W and 400 W with specialized products for building integrated PV systems (BIPV) at even larger sizes. Wafer-based crystalline silicon modules have commercial efficiencies between 14 and 24,1%. Crystalline silicon modules consist of individual PV cells connected together and encapsulated between a transparent front, usually glass, and a backing material, usually plastic or glass. Thin-film modules encapsulate PV cells formed into a single substrate, in a flexible or fixed module, with transparent plastic or glass as the front material. Their efficiency ranges between 7% (a-Si) and 18,1% (CdTe). CPV modules offer now efficiencies above 38%.

A **PV System** consists in one or several PV modules, connected to either an electricity network (grid-connected PV) or to a series of loads (off-grid). It comprises various electric devices aiming at adapting the electricity output of the module(s) to the standards of the network or the load: inverters, charge controllers or batteries.

PV TECHNOLOGY / CONTINUED

A wide range of **mounting structures** has been developed especially for BIPV; including PV facades, sloped and flat roof mountings, integrated (opaque or semi-transparent) glass-glass modules and "PV roof tiles". Single or two-axis **tracking systems** have recently become more and more attractive for ground-mounted systems, particularly for PV utilization in countries with a high share of direct irradiation. By using such systems, the energy yield can typically be increased by 25-35% for single axis trackers and 35-45% for double axis trackers compared with fixed systems.

GRID-CONNECTED PV SYSTEMS

In grid-connected PV systems, an **inverter** is used to convert electricity from direct current (DC) as produced by the PV array to alternating current (AC) that is then supplied to the electricity network. The typical weighted conversion efficiency is in the range of 95% to 99%. Most inverters incorporate a Maximum Power Point Tracker (MPPT), which continuously adjusts the load impedance to provide the maximum power from the PV array. One inverter can be used for the whole array or separate inverters may be used for each "string" of modules. PV modules with integrated inverters, usually referred to as "AC modules", can be directly connected to the electricity network (where approved by network operators) and play an increasing role in certain markets.

OFF-GRID PV SYSTEMS

For off-grid systems, a **storage battery** is required to provide energy during low-light periods. Nearly all batteries used for PV systems are of the deep discharge lead-acid type. Other types of batteries (e. g. NiCad, NiMH, Li-Ion) are also suitable and have the advantage that they cannot be over-charged or deep-discharged, but these 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 even if progresses are seen in that field.

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 AC electricity, a "**stand-alone inverter**" can supply conventional AC appliances.

PV APPLICATIONS AND MARKET SEGMENTS

There are six primary applications for PV power systems starting from small pico systems of some watts to very large-scale PV plants of hundreds of MW.

Pico PV systems have experienced significant development in the last few years, combining the use of very efficient lights (mostly LEDs) with sophisticated charge controllers and efficient batteries. With a small PV panel of only a few watts, essential services can be provided, such as lighting, phone charging and powering a radio or a small computer. Expandable versions of solar pico PV systems have entered the market and enable starting with a small kit and adding extra loads later. They are mainly used for off-grid basic electrification, mainly in developing countries.

Off-grid domestic systems provide electricity to households and villages that are not connected to the utility electricity network (also referred to as 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 up to 5 kW in size.

Generally they 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.

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 telecommunications, 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.

Hybrid systems combine the advantages of PV and diesel generator in mini grids. They allow mitigating fuel price increases, deliver operating cost reductions, and offer higher service quality than traditional single-source generation systems. The combining of technologies provides new possibilities. The micro-hybrid system range for use as a reliable and cost-effective power source for telecom base stations continues to develop and expand. The development of small distributed hybrid generation systems for rural electrification to address the needs of remote communities will rely on the impetus given by institutions in charge of providing public services to rural customers. Large-scale hybrids can be used for large cities powered today by diesel generators and have been seen for instance in central Africa for powering cities far from the grid with a base of utility-scale PV and battery storage.

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 distribution network is configured to supply power to a number of customers rather than to provide a bulk transport function). Such systems may be on, or integrated into, the customer's premises often on the demand side of the electricity meter, on residential, commercial or industrial 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 rooftop may be large by PV standards, this is not the case for other forms of distributed generation. On buildings, we have to distinguish between BAPV and BIPV systems. BAPV refers to PV systems installed on an existing building while BIPV imposes to replace conventional building materials by PV ones.

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.


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PV MARKET DEVELOPMENT TRENDS

More than twenty years of PV market development have resulted in the deployment of more than 303 GW of PV systems all over the world. However, the diversity of PV markets calls for an in-depth look at the way PV has been developing in all major markets, in order to better understand the drivers of this growth.

METHODOLOGY

This report counts all installations, both grid-connected and reported off-grid installations. By convention, the numbers reported refer to the nominal power of PV systems installed. These are expressed in W (or Wp). Some countries are reporting the power output of the PV inverter (device converting DC power from the PV system into AC electricity compatible with standard electricity networks). The difference between the standard DC Power (in Wp) and the AC power can range from as little as 5% (conversion losses) to as much as 40% (for instance some grid regulations limit output to as little as 65% of the peak power from the PV system, but also higher DC/AC ratios reflect the evolution of utility-scale PV systems). Conversion of AC data has been made when necessary, in order to calculate the most precise installation numbers every year. Global totals should be considered as indications rather than exact statistics. Data from countries outside of the IEA PVPS network have been obtained through different sources, some of them based on trade statistics.

THE GLOBAL PV INSTALLED CAPACITY

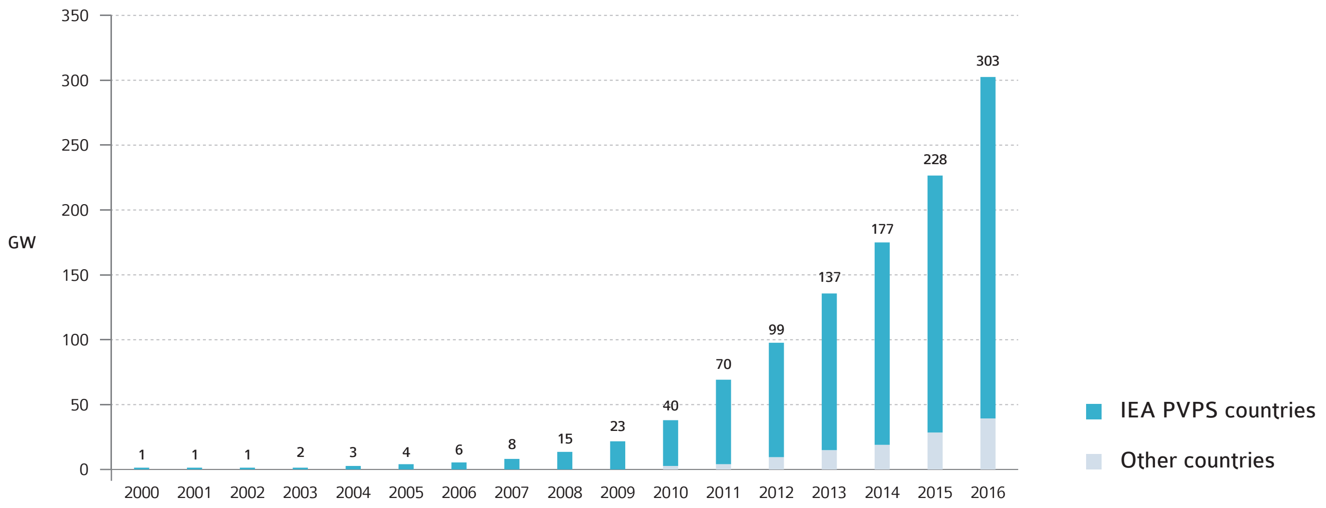
The IEA PVPS countries represented more than 264 GW of cumulative PV installations altogether, mostly grid-connected, at the end of 2016. The other 38 countries that have been considered and are not part of the IEA PVPS Programme represented 40 additional GW. An historical part is located in Europe: UK with almost 12 GW, Greece with 2,6 GW, Czech Republic with 2,2 GW installed, Romania with 1,4 GW, Bulgaria with 1,0 GW and Ukraine and Slovakia below the GW mark. The other major countries that accounted for the highest cumulative installations at the end of 2016 are India with more than 9 GW, South Africa with 1 GW, Taiwan with 1,2 GW, Pakistan with an estimated 1 GW, Ukraine with 0,7 GW and the Philippines with 0,9 GW. Numerous countries all over the world have started to develop PV but few have yet reached a significant development level in terms of cumulative installed capacity at the end of 2016 outside the ones mentioned above. According to a paper released in 2017[1] 49 countries had a least 100 MW cumulative at the end of 2016 and 58 countries had more than 10 MW.

Presently it appears that 303 GW represents the minimum installed by end of 2016 with a firm level of certainty.

1 "Latest Developments in Global Installed Photovoltaic Capacity and Identification of Hidden Growth Markets", Werner Ch., Gerlach A., Masson G., Breyer Ch., 2017.

THE GLOBAL PV INSTALLED CAPACITY / CONTINUED

FIGURE 1: EVOLUTION OF CUMULATIVE PV INSTALLATIONS (GW)



SOURCE IEA PVPS & OTHERS.

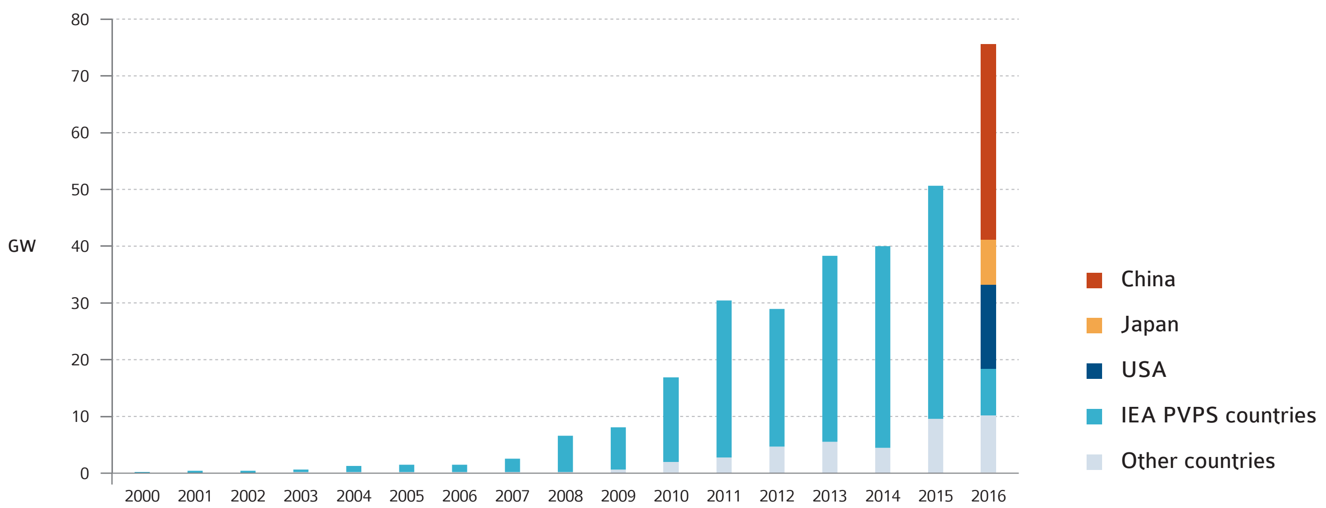
THE MARKET EVOLUTION

The 26 IEA PVPS countries installed at least 65,5 GW in 2016, with a worldwide installed capacity amounting to close to 76 GW. While they are more difficult to track with a high level of certainty, installations in non IEA PVPS countries contributed for 10,2 GW. The remarkable trend of 2016 is again the significant growth of the global PV market after the slight growth experienced during 2013 - 2014. With close to 76 GW, the market grew in 2016 by around 50%, again the highest installation ever for PV.

For the fourth year in a row, **China** is in first place and installed 34,55 GW in 2016, according to the National Energy Administration; a record level significantly higher than the 10 GW that placed the country in first place in 2013 and then in 2014, with regard to all time PV installations. China more than doubled their 2015 installation numbers that saw 15,15 GW being installed. The total installed capacity in China reached 78 GW, and confirms the country as the key leader, even if the European Union passed the 100 GW mark.

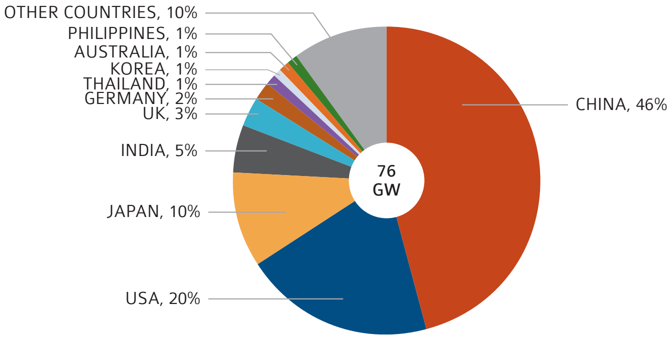
The **USA** is in second place this year with 14,7 GW installed, out of which 10 GW were installed as utility-scale plants.

FIGURE 2: EVOLUTION OF ANNUAL PV INSTALLATIONS (GW)



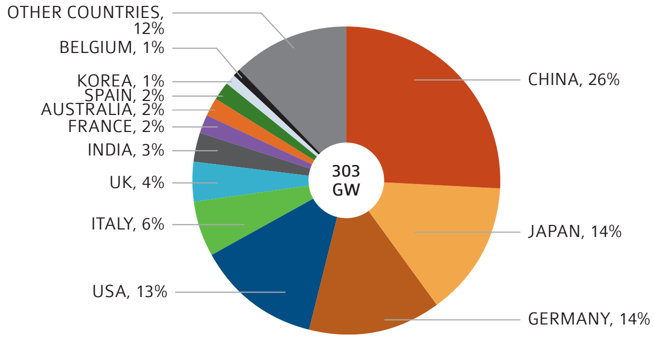
SOURCE IEA PVPS & OTHERS.

FIGURE 3: GLOBAL PV MARKET IN 2016



SOURCE IEA PVPS & OTHERS.

FIGURE 4: CUMULATIVE PV CAPACITY END 2016



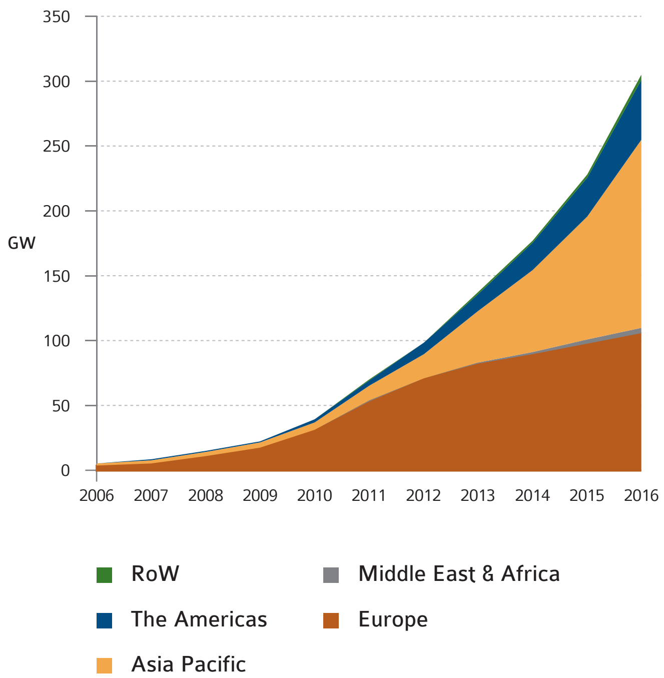
SOURCE IEA PVPS & OTHERS.

At the same time, the market in **Japan** decreased to 7,9 GW installed in the country in 2016. From the record-high level in the last two years, the Japanese PV market went slightly down.

The **European Union** bloc of countries remains in fourth place, with 6,2 GW installed, down from the already low 8,6 GW from 2015 and far from the 2011 level.

India confirmed its tremendous potential with 4 GW installed in 2016, with much more to come in the years ahead.

FIGURE 5: EVOLUTION OF REGIONAL PV INSTALLATIONS (GW)



SOURCE IEA PVPS & OTHERS.

Together, these five leading countries or bloc of countries represented 88 % of all installations recorded in 2016 and 89% in terms of installed capacity. This shows how the global PV market remains concentrated in a limited number of markets. This also shows the current market rebalancing, with the largest countries and largest electricity consumers taking the lead for annual installations.

Looking at the ranking of European Union countries, **UK** (fifth) installed slightly more than 2,2 GW in 2016, after having installed over 4 GW in 2015. Despite the expected market decline, the country scored the first rank again amongst European countries. **Germany** (sixth) saw its market stabilizing: from 1,9 GW in 2014, the 2015 German PV market reached 1,45 GW and in 2016 reached 1,48 GW, well below the 2008 level. After three years at levels of PV installations around 7,5 GW, the German PV market declined significantly. The total installed PV capacity has now passed the 41 GW mark, but is now ranked number three behind **China** and **Japan** and slightly above the **USA**.

The last country to reach the GW mark in 2016 was **Thailand** (seventh), which installed slightly more than 1 GW, bringing the total installed capacity in the country to 2,4 GW. After five years of installations between 100 and 500 MW, Thailand confirmed its potential for the years to come.

No additional country installed more than 1 GW in 2016, showing that while the PV market reaches new countries, a very large part of the market remains concentrated in the hands of few countries.

Eighth on the list, **Korea** confirmed its market potential by installing 0,9 GW in 2016, a level similar to the one reaching in the last two years, and **Australia** at the ninth position saw its market declining by around 10% at 0,88 GW. At the 10th position, the **Philippines** installed close to 759 MW, a market fueled by utility-scale installations.

Together these 10 countries cover 95% of the 2016 world market, a figure that has remained stable in the last years. Moreover, the level of installation required to enter the top 10 has decreased since 2013, and then increased again: from 843 MW, it went down

THE MARKET EVOLUTION / CONTINUED

to 675 MW in 2015, and rose again to 759 MW in 2016, a sign that the growth of the global PV market has been driven by top countries, while others are contributing marginally, still in 2016; fueling fears for the market stability if one of the top three markets, and especially **China**, would experience a slowdown.

Behind the top ten, some countries installed significant amounts of PV. **Turkey** installed 583 MW, in progress and **France** installed 559 MW, going down significantly compared to previous years despite a real change in policies. The **Netherlands** installed with 525 MW, together with **Chile** (495MW), **Italy** (382 MW) and **Israel** (130 MW). **South Africa** installed officially 70 MW and **Canada** 143 MW.

Among these countries, some have already reached high PV capacities due to past installations. This is the case for **Italy** that tops 19,3 GW but also for the **Netherlands** which has reached the 2 GW mark, **Romania** with 1,4 GW and **Israel** is approaching 1 GW.

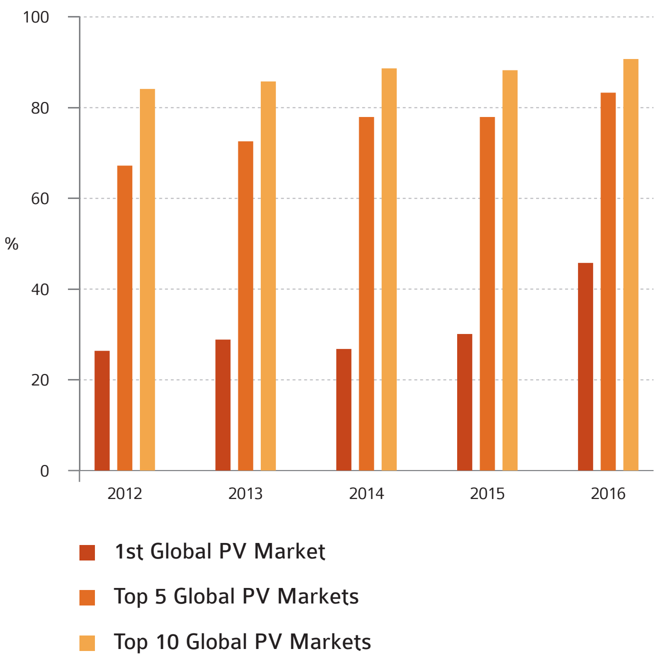
In Europe, several other countries where the PV market used to develop in the last years, have performed in various ways. **Belgium** installed 173 MW and has reached 3,4 GW. Some countries that grew dramatically over recent years have now stalled or experienced limited additions: **Spain** (55 MW) now totals 4,7 GWac of PV systems (respectively DC calculation 58 MWdc and 5,5 GWdc), followed by the **Czech Republic** at 2,2 GW and **Switzerland** at 1,66 GW. In **Denmark**, the market that experienced a rebound due to utility-scale installations in 2015 went down again: the distributed PV market that developed thanks to the net-metering scheme remained at a low level. **Denmark** installed a total of 71 MW. **Austria** continued at the same place with 155 MWac (roughly 171 MWdc), compared to 151 MW of the year before. **Sweden**, **Finland** and **Norway** reached respectively 79 MW, 37,4 MW and 26,6 MW of cumulative installed capacity with markets growing at a low level.

In Asia, **Malaysia** installed 72 MW for the fifth year of its Feed-in Tariff (FiT) system. **Taiwan** installed 369 MW in a growing market now supported by pro-solar policymakers and many other countries in the region have started to implement PV policies.

In Latin America, **Chile** leads installation capacity with 495 MW in 2016. Projects are popping up in Brazil and Honduras. **Honduras** installed 391 MW in 2015, but this outcome was not repeated in 2016. The real PV development of grid-connected PV plants has finally started and additional countries have installed dozens of MW. Among the most promising prospects in the region, **Mexico** installed close to 143 MW but several GW have been granted to developers, which might transform the country into the very first GW-size market in Latin America.

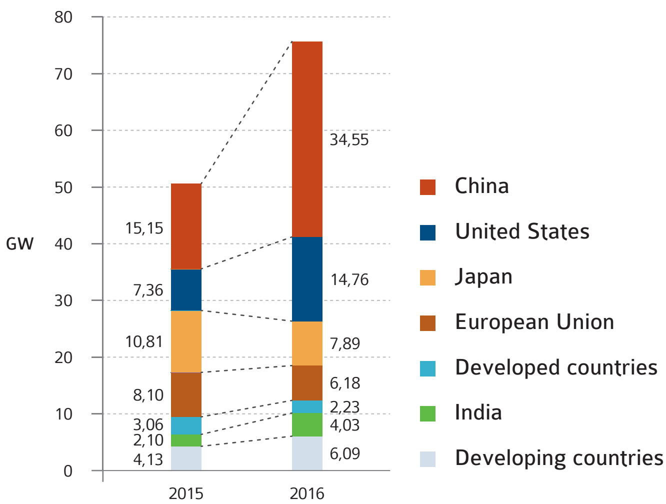
In the Middle East, with hundreds of MW of projects granted to super competitive tenders in Jordan or the UAE, the MENA region seems on the verge of becoming a new focal point for PV development, especially with the extremely low PPA granted there: **Jordan** installed more than 150 MW. Finally, Africa also sees PV deployment, with **Algeria** having installed 268 MW in 2015 and 54 MW more in 2016. **South Africa** commissioned around 70 MW after a rapid expansion in 2014 and more is already granted for the years to come. Many other countries are experiencing some PV development, from **Morocco** to **Ghana** or even **Nigeria**, with double-digit MW markets.

FIGURE 6: EVOLUTION OF MARKET SHARE OF TOP COUNTRIES



SOURCE IEA PVPS & OTHERS.

FIGURE 7: 2015-2016 GROWTH PER REGION



SOURCE IEA PVPS & OTHERS.

A TRULY GLOBAL MARKET

While large markets such as Germany or Italy have exchanged the first two places from 2010 to 2012, China, Japan and the USA scored the top three places from 2013 to 2016, with the USA jumping to second place in 2016. Seven of the top ten leaders in 2012 are still present while the others have varied from one year to another. The UK entered the top ten in 2013, Korea in 2014 and Thailand in 2016. Greece left in 2013 and Canada in 2016. Romania entered the top 10 in 2013 and left in 2014. France came back in 2014 and confirmed its position in 2015 before leaving in 2016. South Africa entered briefly in 2014 and left already in 2015. The number of small-size countries with impressive and unsustainable market evolutions declined, especially in Europe but some booming markets in 2016 could experience a similar fate. For example, Honduras lost its newly acquired position in 2016. In 2014, only major markets reached the top 10, the end of a long term trend that has seen small European markets booming during one year before collapsing. The Czech Republic experienced a dramatic market uptake in 2010, immediately followed by a collapse. Belgium and Greece installed hundreds of MW several years in a row. Greece and Romania scored the GW mark in 2013 before collapsing. 2014 started to show a more reasonable market split, with China, Japan and the USA climbing up to the top places, while India, the UK and Australia confirmed their market potential, as in 2015 and 2016. However, the required market level for entry into this top ten that grew quite fast until 2012, declined until 2015 and increased slightly in 2016. In 2016, only 759 MW were necessary to reach the top ten, compared to 843 MW in 2012, while the global PV market surged from 30 to almost 76 GW at the same time. The number of GW markets that declined in 2014 to only five grew again to eight in 2015 and went down to seven in 2016. Some countries were rather close to the 1 GW mark (Korea, Australia) in 2016 after having scored such a level in recent years. It can be seen as a fact that the growth of the PV market took place in countries with already well-established markets, while booming markets did not contribute significantly in 2016, again.

UTILITY-SCALE PROJECTS CONTINUE TO THRIVE

The most remarkable trend of 2016 is again the announcement of extremely competitive utility-scale PV projects in dozens of new countries around the world and the confirmation that previous announcements were followed by real installations. Projects are popping up and even if some of them will not be realized in the end, it is expected that installation numbers will start to be visible in countries where PV development was limited until now. More countries are proposing calls for tenders in order to select the most competitive projects, which trigger a significant decline in the value of PPAs and enlarge horizons for PV development. Utility-scale PV installations have surged significantly in 2016 with more at 55 GW compared to only 21 GW two years earlier. Many countries are proposing new tenders, including Germany, the UAE, Jordan, Brazil, Mexico and others. Due to the necessity to compete with low wholesale electricity prices, tenders offer an alternative to free installations but constrain the market, while favouring the most competitive solutions (and not always the most innovative, unless mentioned explicitly).

PROSUMERS, A CHALLENGING BUT PROMISING FUTURE

The progressive move towards self-consumption schemes has been identified in many countries. While established markets such as Belgium or Denmark are moving away from net-metering on a progressive base (through taxation, for instance), emerging PV markets are expected to set up net-metering schemes. They are easier to set in place and do not require investment in complex market access or regulation for the excess PV electricity. Net-metering has been announced or implemented in the UAE, Lebanon, Chile, some Indian states and other countries. The trend goes in the direction of self-consuming PV electricity, with adequate regulations offering a value for the excess electricity, either through FiT, net-metering, or net-billing, as it can be seen in several countries, such as the USA. However the move towards self-consumption creates difficulties for the PV sector and the distributed PV market has been stable for five years now. It has been oscillating around 16-19 GW since 2011. While utility-scale PV develops, distributed PV experiences a real stagnation with little progress thus far. The US market can be seen as an exception, in the same way as several European PV markets that are currently transitioning towards self-consumption. However, the move towards distributed PV for prosumers has been delayed, a perspective that the massive development of PV in China and soon India could help reversing.

LARGEST ADDITIONS EVER

The paradox of PV developing thanks to utility-scale installations is hidden by the remarkable progress of many markets. Italy's record of 9,3 GW yearly installed power was beaten in 2013 by China with its 10,95 GW; but also by Japan in 2015 with 10,8 GW. Then, even more by China in 2015 that installed 15,15 GW, and again in 2016 with 34,55 GW. And more is expected in 2017. With one country, China reaching levels of installations never seen before and higher than the global PV market until 2014, 2016 confirms that the 34,55 GW reached for the year are translated in other beaten records.

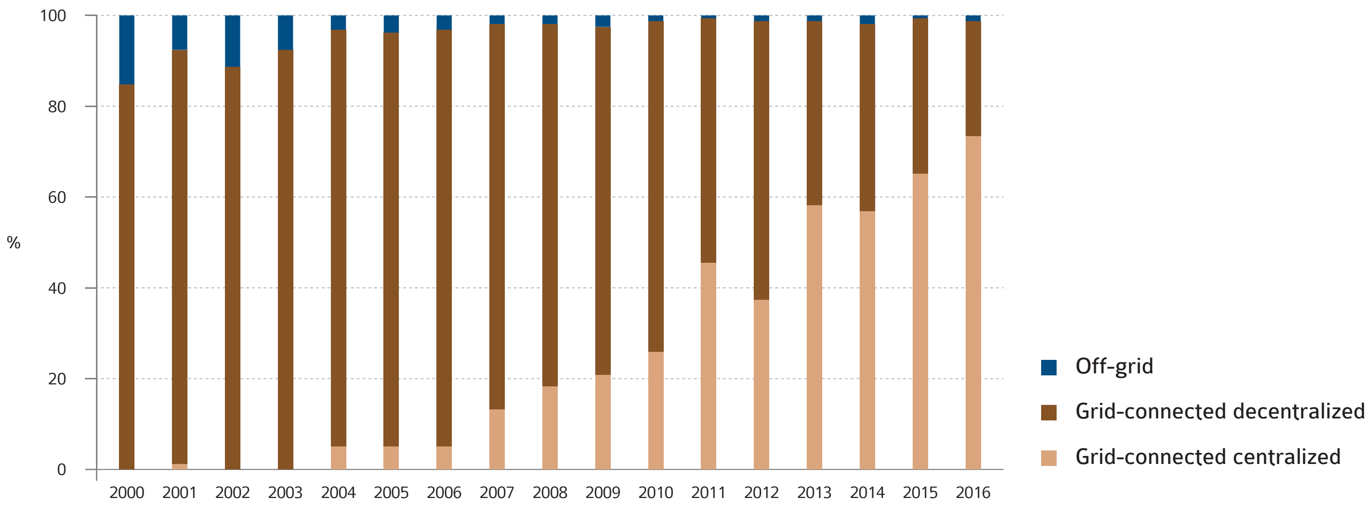
TABLE 1: EVOLUTION OF TOP 10 PV MARKETS

RANKING	2014	2015	2016
1	CHINA	CHINA	CHINA
2	JAPAN	JAPAN	USA
3	USA	USA	JAPAN
4	UK	UK	INDIA
5	GERMANY	INDIA	UK
6	FRANCE	GERMANY	GERMANY
7	KOREA	AUSTRALIA	THAILAND
8	AUSTRALIA	KOREA	KOREA
9	SOUTH AFRICA	FRANCE	AUSTRALIA
10	INDIA	CANADA	PHILIPPINES
MARKET LEVEL TO ACCESS THE TOP 10			
	779 MW	675 MW	759 MW

SOURCE IEA PVPS & OTHERS.

THE MARKET EVOLUTION / CONTINUED

FIGURE 8: SHARE OF GRID-CONNECTED AND OFF-GRID INSTALLATIONS 2000-2016

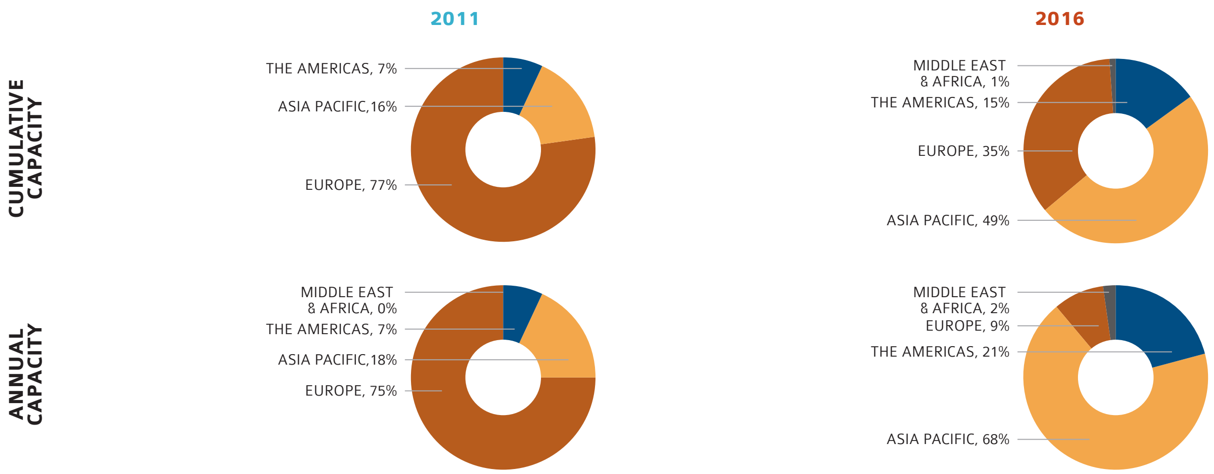


SOURCE IEA PVPS & OTHERS.

OFF-GRID MARKET DEVELOPMENT

The off-grid market can hardly be compared to the grid-connected market. The rapid deployment of grid-connected PV dwarfed the off-grid market as Figure 8 clearly shows. Numbers for off-grid applications are in general not tracked with the same level of accuracy as grid-connected applications. However the development of PV in dozens of developing countries provides a picture of the off-grid market size, with huge uncertainties on the numbers anyway.

FIGURE 9: EVOLUTION OF ANNUAL AND CUMULATIVE PV CAPACITY BY REGION 2011-2016 (MW)



	CUMULATIVE CAPACITY (MW)						ANNUAL CAPACITY (MW)					
REGION	2011	2012	2013	2014	2015	2016	2011	2012	2013	2014	2015	2016
THE AMERICAS	4 585	8 295	13 616	20 844	29 783	45 558	2 233	3 710	5 320	7 228	8 940	15 775
ASIA PACIFIC	11 135	18 053	39 864	63 719	95 079	145 903	5 394	7 918	21 812	23 855	31 359	50 824
EUROPE	53 866	71 277	82 067	89 253	97 876	104 551	22 694	17 411	10 790	7 186	8 623	6 675
MIDDLE EAST & AFRICA	211	276	731	1 786	2 571	3 674	127	65	455	1 055	785	1 103
REST OF THE WORLD	371	633	917	1 363	2 360	3 709	145	262	284	447	996	1 349

SOURCE IEA PVPS & OTHERS.

Nevertheless, off-grid applications are developing more rapidly in several countries than in the past and some targeted support has been implemented.

In Australia, 36 MW of off-grid systems have been installed in 2016, bringing the total to 210 MW. In China, some estimates showed that 10 MW of off-grid applications have been installed in 2016, with an unknown percentage of hybrid systems and mobile products. It can be considered that most industrial applications and rural electrification systems are most probably hybrid. It must be noted that China has reached 100% of electrification in 2015, which will in any case significantly reduce the level of off-grid installations in the future. Japan has reported 34 MW of off-grid applications in 2016, significantly higher than in 2015; bringing the installed capacity above 150 MW, mainly in the non-domestic segment.

In most European countries, the off-grid market remains a very small one, mainly for remote sites, leisure and communication devices that deliver electricity for specific uses. Some mountain sites are equipped with PV as an alternative to bringing fuel to remote, hardly accessible places. However, this market remains quite small, with at most some MW installed per year per country, for instance with around 1,5 MW in Sweden.

In some countries, off-grid systems with back-up (either diesel generators or chemical batteries) represent an alternative in order to bring the grid into remote areas. This trend is specific to countries that have enough solar resource throughout the year to make a PV system viable. In Africa for instance, PV has been seen being deployed to power off-grid cities and villages. The example of the city of Manono in Katanga (DR Congo) shows how off-grid applications are becoming mainstream and increase also in size: 1 MW of ground-mounted PV with 3 MWh of battery-storage powers up the city and opens a brand new market for large-scale off-grid PV applications.

In most developed countries in Europe, Asia or the Americas, this trend remains unseen and the future development of off-grid applications will most probably be seen first on remote islands. The case of Greece is rather interesting in Europe, with numerous islands not connected to the mainland grid that have installed dozens of MW of PV systems in the previous years. These systems, providing electricity to some thousands of customers will require rapid adaptation of the management of these mini-grids in order to cope with high penetrations of PV. The French islands in the Caribbean Sea and the Indian Ocean have already imposed specific grid codes to PV system owners: PV production must be forecasted and announced in order to better plan grid management. As an example, Reunion Island (France) operated more than 189 MW of PV at the end of 2016 for a total population of 840 000. High PV penetration levels on several islands have direct consequences on the share of PV electricity: in Kiribati, this percentage reaches 12,3%, in Cape Verde 6,7%, and around 5% in Malta, Comoros and Solomon Islands.

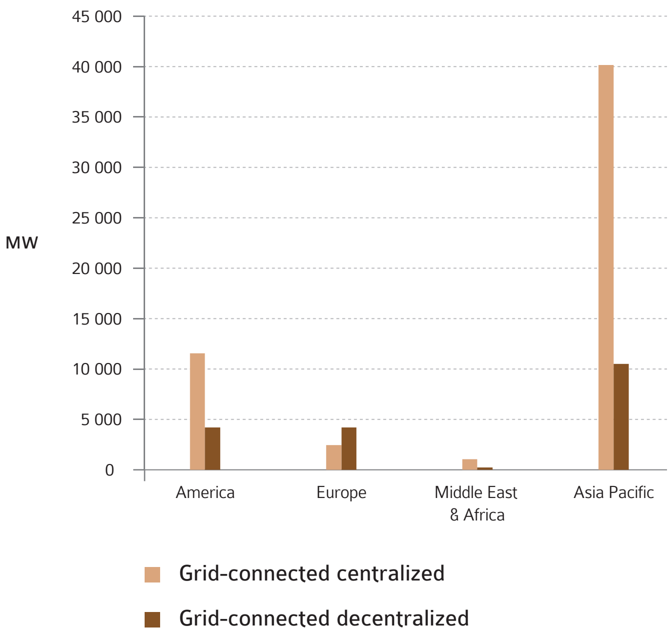
Off-grid SHS systems (small PV systems with a small battery) have developed rapidly in the last years, with six million systems installed worldwide. Outside the IEA PVPS network, Bangladesh installed an impressive amount of these off-grid SHS systems in recent years. More than four million systems were operational by the end of 2016 with at least 180 MW installed. Six million PV installations providing basic electricity needs for more than thirty million people were expected by end 2017.

In Latin America, Peru has committed to a program of rural electrification with PV, as is the case in many other countries.

India has foreseen up to 2 GW of off-grid installations by 2017, including twenty million solar lights in its National Solar Mission. These impressive numbers show how PV now represents a competitive alternative to providing electricity in areas where traditional grids have not yet been deployed. In the same way as mobile phones are connecting people without the traditional lines, PV is perceived as a way to provide electricity without first building complex and costly grids. The challenge of providing electricity for lighting and communication, including access to the Internet, will see the progress of PV as one of the most reliable and promising sources of electricity in developing countries in the coming years.

In China, the solar program allows building PV plants on buildings in remote areas to fight poverty. This poverty alleviation program has already led to several GW of PV installations and continues in 2017.

FIGURE 10: GRID-CONNECTED CENTRALIZED & DECENTRALIZED PV INSTALLATIONS BY REGION IN 2016



SOURCE IEA PVPS,Chris Werner Energy Consulting, Alexander Gerlach Consulting.

THE MARKET EVOLUTION / CONTINUED

THE ENERGY STORAGE MARKET

While 2015 was a year of significant announcements with regard to electricity storage, in comparison 2016 delivered little. The market is not moving quickly, except in some specific countries. The reason is rather simple: few incentives exist and the number of markets where electricity storage could be competitive is reduced. As a matter of fact, only Germany has incentives for battery storage in PV systems, Italy has a tax rebate and some Swiss cantons have subsidy schemes. In Germany during the year 2016, the installation of storage systems was funded for 6 468 storage systems (800 for existing and 5 668 for newly installed PV systems), with the total volume of loans reaching 105 MEUR.

In the USA, California has funded up to-date approximately 59 MW of storage, and 280 storage projects. In Hawaii, 17 utility-led energy storage projects have been supported. In the French overseas' departments (including Corsica), a call for tenders for 50 MW of PV systems above 100 kW with storage has been initiated in 2015, aiming at increasing the grid stability. The winning candidates for this Call have been announced in June 2016. Out of 356 MW of submitted projects, 52 MW were selected with an average contract tariff of 204 EUR/MWh. Half of the volume will be built in the French Antilles (including French Guyana). Half of the volume will be ground mounted or parking canopy systems, the rest will be installed in buildings.

In Japan, projects to install storage batteries are also increasing but they are limited by subsidies since the cost remains high. Storage batteries for residential applications are part of a subsidy program to accelerate the development of net zero energy houses. For this subsidy program, five rounds of public invitation were carried out, which received 6 368 applications in total. Other subsidy for storage batteries are available in Japan.

In general, battery storage is seen by some as an opportunity to solve some grid integration issues linked to PV and to increase the self-consumption ratios of PV plants. However, the cost of such a solution prevents them from largely being used for the time being. On large-scale PV plants, batteries can be used to stabilize grid injection and in some cases, to provide ancillary services to the grid.

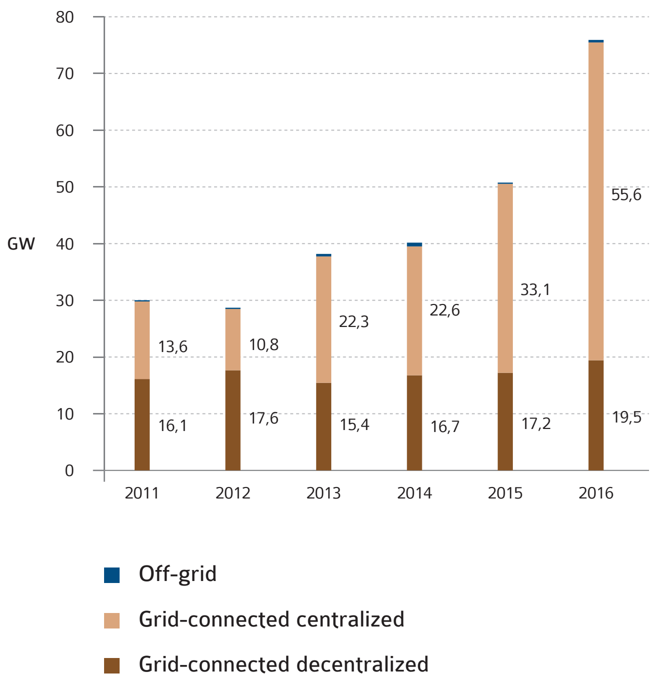
THE ELECTRIFICATION OF TRANSPORT, HEATING AND COOLING.

The energy transition will require electricity to become the main vector for applications that used to consume fossil fuels, directly or indirectly. In that respect, the development of solar heating and cooling hasn't experienced major developments in 2016, on the contrary to electric mobility that starts to develop fast in several countries: China intends that 10% of all cars sold in China in 2019 should be fully electric or plug-in hybrids. In parallel, more and more countries announced that fossil-fueled cars will be banned from the market from 2030 or 2040. Automotive manufacturers are announcing the electrification of the entire fleet in the coming years, even if the market remains small in most countries. With more than 730 000 electric vehicles sold in the world in 2016 and more than one million expected during the year 2017, the automotive sector is moving quickly towards connecting to the electricity industry.

The role of PV as an enabler of that energy transition is more and more obvious and the idea of powering mobility with solar is becoming slowly a reality thanks to joint commercial offers for PV and storage.

PV DEVELOPMENT PER REGION AND SEGMENT

FIGURE 11: SEGMENTATION OF PV INSTALLATIONS 2011 – 2016



SOURCE IEA PVPS & OTHERS.

The evolution of grid-connected PV towards a balanced segmentation between centralized and decentralized PV reversed course in 2013 and continued its trend in 2016. Centralized PV has evolved faster and most of the major PV developments in emerging PV markets are coming from utility-scale PV. This evolution has different causes. Utility-scale PV requires developers and financing institutions to set up plants in a relatively short time. This option allows the start of using PV electricity in a country faster than what distributed PV requires. Moreover, 2016 saw remarkable progress again in terms of PV electricity prices through tenders that are making PV electricity even more attractive in some regions. However, utility-scale has been also criticized when considering environmental concerns about the use of agricultural land, difficulties in reaching competitiveness with wholesale electricity prices in this segment, and grid connection issues, for example. However, recent developments with extremely competitive tenders below 30 USD/MWh have contributed to the increase of the utility-scale market in 2016. Globally, centralized PV represented more than 70% of the market in 2016, mainly driven by China, the USA, and emerging PV markets.

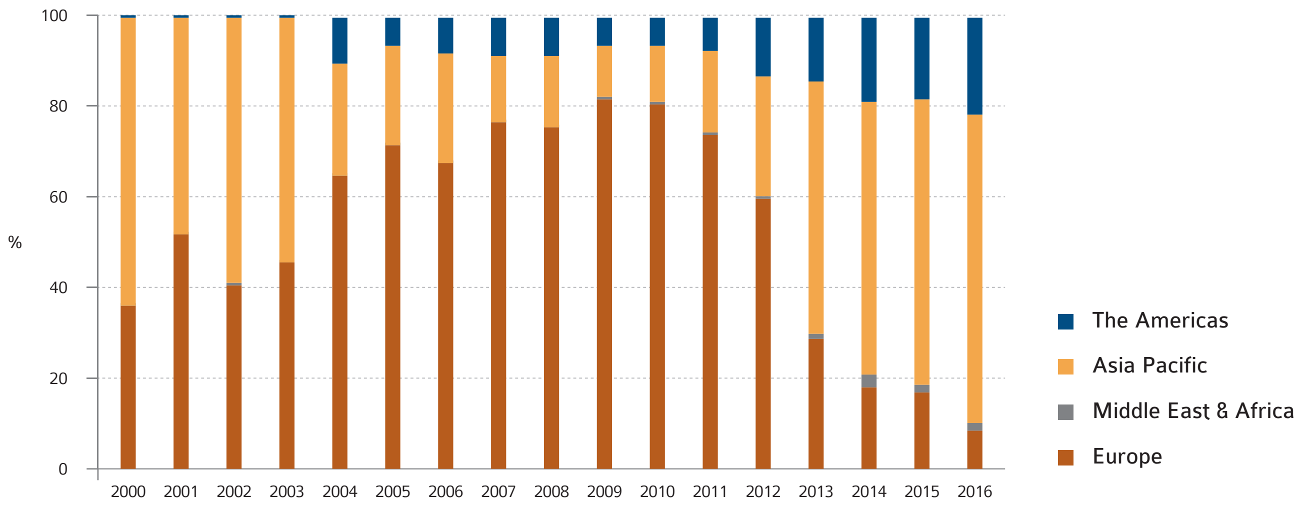
The same pattern between decentralized and centralized PV is visible in the Asia Pacific region and in the Americas, with a domination of centralized PV installations. This should not change in the coming years, with the arrival of more developing countries that could focus on pure electricity generation rather than self-consumption driven business models. The availability of cheap capital for financing large-scale PV installations also reinforces this evolution and reduces the development of rooftop PV even further. This becomes clearly visible with utility-scale growing again in 2016 while the rooftop market stagnated.

Figure 12 illustrates the evolution of the share of grid-connected PV installations per region from 2000 to 2016. While Asia started to dominate the market in the early 2000s, the start of FiT-based incentives in Europe, and particularly in Germany, caused a major market uptake in Europe. While the market size grew from around 200 MW in 2000 to above a GW in 2004, the market started to grow very fast, thanks to European markets in 2004. From around 1 GW in 2004, the market reached close to 2 GW in 2007. In 2008, Spain fuelled market development while Europe achieved more than 80% of the global market: a performance repeated until 2010.

The share of Asia and the Americas started to grow rapidly from 2012, with Asia taking the lead. This evolution is quite visible from 2011 to 2016, with the share of the Asia-Pacific region growing from 18% to more than 60%, whereas the European share of the PV market went down from 74% to around 10% in six years. This trend shows that the global development of PV is not in the hands of European countries anymore.

Finally, the share of the PV market in the Middle East and in Africa remains relatively small compared to other regions of the world, despite the growth of the South African market and the numerous projects in UAE, Jordan, Turkey and Algeria.

FIGURE 12: SHARE OF GRID-CONNECTED PV MARKET PER REGION 2000-2016



SOURCE IEA PVPS,Chris Werner Energy Consulting, Alexander Gerlach Consulting.

THE AMERICAS

The Americas represented 15,8 GW of installations and a total cumulative capacity of 45,6 GW in 2016. If most of these capacities are located in the USA, and in general in North America, several countries have started to install PV in the central and southern parts of the continent; especially in Chile and Honduras in 2015 and 2016 and many other markets such as Mexico are promising.

CANADA

FINAL ELECTRICITY CONSUMPTION 2016	561	TWh
HABITANTS 2016	36	MILLION
IRRADIATION	1 150	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	143	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	2 723	MW
PV PENETRATION	0,5	%

At the end of 2016, the installed capacity of PV systems in Canada reached more than 2,7 GW, out of which 143 MW were installed in 2016, a significant market decrease compared to previous years. Decentralized rooftop applications amounted to around 54 MW compared to 268 MW two years earlier. Large-scale centralized PV systems continued to lead the market with a yearly installed capacity of 89 MW in 2016 (significantly down from 480 MW in 2015). The market was dominated by grid-connected systems: Prior to 2008, PV was serving mainly the off-grid market in Canada. Then the FiT programme created a significant market development in the province of Ontario. Installations in Canada are still largely concentrated in Ontario (approximately 99%) and driven mostly by the province's policies. For comparison, the cumulative installed PV capacity in Alberta, British Columbia, and Saskatchewan at the end of 2016 was 16,9 MW, 6,5 MW, and 5,3 MW, respectively.

Ontario's Feed-in Tariff Programme: While net-metering support schemes for PV have been implemented in most provinces, the development took place mostly in Ontario. This province runs a FiT system (micro-FiT for systems below 10 kW) with an annual target of 50 MW. The FiT scheme that targets generators above 10 kW and up to 500 kW has evolved to include a tendering process. Eligible PV systems are granted a FiT or microFiT contract for a period of 20 years. In 2016, the FiT levels were reviewed and tariffs were reduced to follow the PV system costs decrease. Above 500 kW, a new system based on a tender (RFQ) was supposed to be opened for 140 MW of PV systems under the name of the "Large Renewable Procurement Program". But, due to oversupply of electricity, it was postponed indefinitely. The FiT program is financed by electricity consumers. Furthermore, net-metering in Ontario allows PV systems up to 500 kW to self-consume part of their electricity and obtain credits for the excess electricity injected into the grid. However, since the FiT scheme remains more attractive, the net-metering remains marginally used.

In other provinces and territories, a 30% and 50% renewable electricity generation target by 2030 has been announced by Alberta and Saskatchewan, respectively. Saskatchewan grants one-time subsidies for PV plants under net-metering connected to the grid. Manitoba offers an upfront subsidy for residential, commercial and industrial PV applications. Rebates are offered in other provinces. Off-grid measures exist to favor the move towards renewables of communities which are not connected and use diesel generators.

Finally, Canada's federal government announced a price on carbon for the entire country starting at 10 CAD per ton in 2018 and increasing until 2022 up to 50 CAD per ton. In summary, the Canadian PV market declined significantly and needs to evolve towards a distributed PV market in more than one province. That challenge will be at the core of needed policy development in the coming years to see PV re-developing in the country after a difficult year 2016.

CHILE

FINAL ELECTRICITY CONSUMPTION 2016	74	TWh
HABITANTS 2016	17	MILLION
IRRADIATION	2 020	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	495	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	1 071	MW
PV PENETRATION	3	%

Chile is one of the countries with the highest solar irradiation and a very low density of population which are making it a perfect location for PV development. With 495 MW installed in 2016, the market is driven by utility-scale installations, especially in the northern part of the country. The distributed market remains small for the time being but could grow in the coming years. The largest amount of PV was installed in the Antofagasta region, followed by neighboring northern regions.

At the end of 2016, around 1,1 GW of PV were operational in the country.

The country has the particularity to be extremely long and divided in four grid zones which are not yet interconnected. The northern grid which hosts a very large part of PV installations should be connected to the central grid in the coming years. In that respect, the penetration of PV in the northern grid has increased very fast while it stagnated in the other regions.

With almost 3 000 kWh/kWp, the yield of PV installations in Chile is amongst the highest in the world and allows reaching extremely low electricity prices. These low prices have simplified the market development since developers can sell PV electricity on the electricity market or have concluded long term PPAs with local heavy electricity consumption's companies.

Tenders have also been implemented for PV and Wind to grant long term contracts. In 2016, a large tender for all energies was designed to provide 12 TWh of electricity per year. Solar won only 720 GWh but appears better positioned for some future ones in 2017. The Solar winner proposed a bid at 29,1 USD/MWh for a project expected to enter into operation in 2021, one of the lowest bids ever registered.

The high altitude and high UV radiation makes also the country a perfect test ground for long term performance in harsh desert environments.

The country has also defined a 20% RES target for 2025, and more ambitious plans could be discussed since that threshold will most probably reached before before the target.

Even though, most of the solar power development has been focused on the deployment of utility scale projects. The local regulation permits final end users who have local renewable based generation to inject their power surplus into the grid. Basically, this mechanism is a net billing scheme where the energy provided by end users is valued at the distribution Company purchasing prize. To date, this means 5,5 MW of solar PV roof top based generation.

MEXICO

FINAL ELECTRICITY CONSUMPTION 2016	262	TWh
HABITANTS 2016	128	MILLION
IRRADIATION	1 780	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	143	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	389	MW
PV PENETRATION	0,3	%

Around around 200 MW of PV systems were installed in Mexico in 2016, increasing the total capacity in the country to 389 MW. While most of them were rooftop PV systems installed under the net-metering scheme until 2015, utility-scale starts to grow slowly. To date, the utility-scale segment has not yet developed as expected but the prospects are bright. The real starting point of PV development in Mexico will most probably be 2017 since several hundreds MW that were expected to come during 2016 were delayed.

The new Law for the Electricity Industry (LEI) and the Law for Energy Transition (LET) approved last December 2015 has been set the legal framework for the massive deployment in Mexico of PV, along with other renewables. These legal frameworks also included the mechanism for the long terms auctions of clean electricity, clean power and clean energy certificates (CEC).

So, based on the legal framework, the Energy Ministry (Secretaria de Energía, SENER) has carried out two electric auctions in Mexico, one at the end of 2015 that ended in July 2016, and the other that began in June 2016 and ended in September 2016.

The results obtained from the first electric auction were positive for PV, with 12 offers accepted, amounting to 3,1 GW, with start dates for operations set during and until 2018. The average cost of these auctions reached 51,32 USD/MWh. The September 2016 auction saw prices going down to an average 33 USD/MWh but only 184 MW of PV were allocated.

In parallel, the Energy Regulatory Commission (CRE) has granted a total of 319 interconnection contract for PV in the period of 2011-2016, giving a total of 9,4 GW. At the end of 2016, 115,6 MW were in operation, 9,3 GW are in the process of being installed or are about to start works, which should generate significant amounts of PV installations in the years to come.

Photovoltaic systems with capacities less than 500 kW do not require a generation permit from the regulator. PV systems for residential use (<10 kW), general purpose (<30 kW) at low voltage (less than 1,0 kV), as well as users with PV up to 500 kW that do not need to use CFE transmission or distribution lines for bringing energy to their loads fall into this category.

Amongst the incentives for PV development, the possibility to achieve accelerated depreciation for PV systems exists at the national level (companies can depreciate 100% of the capital investment during the first year) and some local incentives such as in Mexico City could help PV to develop locally.

The price of PV electricity for households with high electricity consumption is already attractive from an economic point of view since they pay more than twice the price of standard consumers. A net-metering scheme (called "Medición Neta") exists for PV systems below 500 kW, mainly in the residential and commercial segments. In 2013, the possibility was added for a group of neighboring consumers (for instance in a condominium) to join together to obtain a permit to produce PV electricity. This specific net-metering scheme resulted in a large part of all installations until 2015. A virtual net-metering scheme exists for large installations, with the possibility to generate electricity in one point of consumption at several distant sites. In this scheme, the utility charges a fee for the use of its transmission and distribution infrastructure.

In December 2012, the National Fund for Energy Savings announced the start of a new financing scheme for PV systems for DAC consumers: five year loans with low interest rates can be used to finance PV systems. Rural electrification is supported through the "Solar Villages programme".

Finally, a 15% import duty has been imposed on PV modules.

USA

FINAL ELECTRICITY CONSUMPTION 2016	4 098	TWh
HABITANTS 2016	324	MILLION
IRRADIATION	1 437	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	14 762	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	40 436	MW
PV PENETRATION	1,3	%

In 2016 the PV annual installed capacity in the USA has almost doubled, from 7,3 GW installed in 2015 to 14,8 GW. Consequently, the PV cumulative capacity has reached the 40 GW threshold at the end of the year 2016, pushing the USA at the fourth rank of all countries. The majority of the 2016 installations developed in the utility-scale segment and are still concentrated in a restricted number of States such as California, Arizona, Nevada, North Carolina, and New Jersey that cover roughly two-thirds of the market.

THE AMERICAS / CONTINUED

As in recent years, net-metering remains the most widespread support measure for distributed PV and it is present in 38 states plus District of Columbia and Puerto Rico. Recently there have been some disputes between utilities and solar advocates over the net-metering and, as a result, several jurisdictions are now approaching the maximum allowed capacity allowed.

Even though during 2016 some incentives has been eliminated such as the solar tax credit which has been cancelled in 4 States and capital subsidies for ground mounted installations expired for 3 States, many project under construction were able to qualify in order to receive fundings.

In 2015, the US Environmental Protection Agency issued final rules for carbon emissions reductions of 30% (from 2005 levels) by a state-by-state approach to be implemented between 2020 – 2030. Additionally, EPA expanded their draft rules to include a Clean Energy Incentive Programme to encourage states to meet carbon reduction goals through wind, solar and energy efficiency, providing substantial incentives to accelerate the deployment of solar and wind technologies in short term. This enforcement was halted by EPA in 2016, under the imposition of the U.S. Supreme Court, after 27 states petitioned the U.S. Court of Appeals for the District of Columbia Circuit for an emergency stay of the Clean Power Plant.

As it concerned self consumption, recently the State of California has started to promote policies in order to encourage energy storage through the Self-Generation Incentive Program that issues incentives between 0,32 and 0,45 USD/Wh according to the size of the implants. Moreover others incentives for self consumption are present in Hawaii State where it has been registered an increase in the smart water heaters, battery storage systems, and other load controls are started to be coupled with PV installations.

The USA's PV market has been mainly driven by the Investment Tax Credit (ITC) and an accelerated 5-year tax depreciation. The ITC was set initially to expire in 2016, however it was finally extended to 2020. Beginning in 2020, the credits will step down gradually until they reach 10% in 2022 for commercial entities and expire for individuals. An expected market boom caused by the ITC cliff didn't happen but a part of the expected installations will take place in the coming years in any case.

As of October 2016, 22 states and Washington DC had RPS policies with specific solar or customer-sited provisions. In 2016, 42 states had laws crediting customers for exported electricity, typically through a "net-metering" arrangement. In the reality these "net-metering" schemes are diverse and cover different realities between pure self-consumption and real net-metering.

Net metering is the most popular process for selling distributed solar energy to the grid and 41 states plus the District of Columbia and Puerto Rico have net metering policies. 18 states modified their net metering policies in 2016. While most of these were minor rule or process changes, 3 states increased their NEM caps, 3 states transitioned to a new compensation program, and two states implemented new self-consumption policies.

3 states currently have FiTs that are accepting new applicants. Some utilities offer feed in tariffs. 15 states are offering capital subsidy, 29 states have set up an RPS (Renewable Portfolio Standard) system out of which 21 have specific PV requirements.

In most cases, the financing of these measures is done through indirect public funding and/or absorbed by utilities.

Third party financing developed fast in the USA, with for instance 60% of residential systems installed under the California Solar Initiative being financed in such a way. Third parties are also widely used to monetize the Investment Tax Credit in cases of insufficient tax appetite. These innovative financing companies cover the high up-front investment through solar leases, for example. Third party financing is led by a limited number of residential third-party development companies, two of them having captured 50% of the market.

Interestingly, due to the continued reduction in system pricing as well as the availability of new loan products and third-party arrangement with lower financing costs, a significant portion of PV systems have recently been installed without any state incentives.

In 2016, loan have emerged as an effective financial mechanism for residential systems and are even beginning to rival third-party ownership in some markets.

With regard to utility-scale PV projects, these are developing under Power Purchase Agreements (PPAs) with utilities. The support of the ITC allows to produce PV electricity at a competitive price, which allows utilities to grant PPAs.

PACE programmes have been enabled in more than 30 states as well; PACE (Property Assessed Clean Energy) is a means of financing renewable energy systems and energy efficiency measures. It also allows avoiding significant upfront investments and eases the inclusion of the PV system cost in case of property sale.

With such a diverse regulatory landscape, and different electricity prices, PV has developed differently across the country. 28 states currently have 50 MW or more PV capacity and 17 states each installed more than 50 MW in 2016 alone. With more than 18 GW of contracted utility scale PV projects in the pipeline as of October, total installations in 2016 are expected to increase yet again.

In December 2012, in an effort to settle claims by US manufacturers that Chinese manufacturers "dumped" product into the US market and received unfair subsidies from the Chinese government, the US Department of Commerce issued orders to begin enforcing duties to be levied on products with Chinese made PV cells. The majority of the tariffs range between 23-34% of the price of the product. In December 2013, new antidumping and countervailing petitions were filed with the US Department of Commerce (DOC) and the United States International Trade Commission (ITC) against Chinese and Taiwanese manufacturers of PV cells and modules. In Q1 2014, the ITC made a preliminary determination, that "there is a reasonable indication that an industry in the United States is materially injured by reason of imports from China and Taiwan of certain crystalline silicon photovoltaic products."1 In December of 2014, the DOC issued its new tariffs for Chinese and Taiwanese cells ranging from 11-30% for Taiwanese companies and 75-91% for Chinese companies.

Finally, state RPS targets require a larger amount of renewable energy additions in 2016 than in previous years, encouraging more growth within the market.

Finally, state RPS targets require a larger amount of renewable energy additions in 2016 than in previous years, encouraging more growth within the market.

OTHER COUNTRIES

Several countries in Central and South America have continued developing in 2016.

Brazil, by far the largest country on the continent, has started to include PV in auctions for new power plants which led to bids at 78 USD/MWh in 2016. In addition, Brazil has now a net-metering system in place but with limited results so far. The government has set up a 3,5 GW target for PV in 2023. With 3 GW of utility-scale PV awarded through auctions to be built before 2018, and 4,5 GW of net-metered installations before 2024, Brazil's PV potential might develop very quickly in the coming years. However, few MW were installed in 2016 but 2017 sees development going on. Projects already announced represent several hundreds of MW that will contribute to market numbers in 2017 and later. Tax exemptions exist in several states, and solar equipment has been excluded from import duties.

In Argentina, the development has been quite small, with only a few MW installed in the country in 2016. Initially the government envisaged 3 GW of renewable energies including 300 MW of PV. However, PV secured significantly more in the first tenders, with 916 MW allocated in 2016. Tenders launched under the "renovAr" program in 2017 were launched with 450 MW set aside for PV. The government envisages 20% of renewable energies in the power mix by 2025, with tenders contributing to 10 GW. The share of PV is not known but will most probably represent several GW.

In Peru, 100 MW of utility-scale plants have been installed in recent years. Several programmes related to rural electrification have also been started. The tenders launched in 2016 led to 185 MW granted to developers with a rather low PPA at 48 USD/MWh at the beginning of 2016.

The PV market in Honduras has experienced a boom during 2015 with 388 MW installed, followed by 45 MW in 2016. However, there is no evidence suggesting that similar measures for PV development will be introduced again in the mid-term. As a result, from 2017 onwards, self-consumption PV systems for the residential and commercial sectors are the main segments envisioned to grow.

Several other countries in Central and Latin America have put support schemes in place for PV electricity, such as Ecuador. Other countries, such as Uruguay or Guatemala have installed several dozens of MW in 2016 through call for tenders. Several other countries including islands in the Caribbean are moving fast towards PV deployment, which could indicate to the time has come for PV in the Americas.

ASIA PACIFIC

The Asia-Pacific region installed close to 50,8 GW in 2016 and more than 145 GW are producing PV electricity. This region again experienced a booming year with 30% as the region annual growth rate.

AUSTRALIA

FINAL ELECTRICITY CONSUMPTION 2016	252	TWh
HABITANTS 2016	24	MILLION
IRRADIATION	1 400	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	876	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	5 985	MW
PV PENETRATION	3,3	%

After having installed 811 MW in 2013, 862 MW in 2014, and 1022 MW in 2015, the Australian market dropped to 876 MW in 2016. The country has more than 5,9 GW of PV systems installed and commissioned, mainly in the residential rooftops segment (more than 1,6 million buildings now have a PV system; an average penetration over the 20% in the residential sector, with peaks up to 50%), with grid-connected applications.

In 2016, the Australian market was mainly driven by a stabilised residential segment (544 MW). The commercial and industrial segment also grew significantly, in contrast to utility-scale projects which plummeted in volume. New domestic off-grid applications amounted in 2016 to 21 MW in the domestic sector (compared to 16 MW in 2015) and 15 MW for non-domestic applications. In total Australia counts 210,2 MW of off-grid systems. PV contributed to 3,3 % of the total electricity consumption in 2016 and will be able to cover at least 2,9 % in 2016 based on the already installed capacity.

Market Drivers

Australian Government support programmes impacted significantly on the PV market in recent years. The 45 000 GWh Renewable Energy Target (RET) (a quota-RPS system) consists of two parts – the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES). In 2016, due to a projected reduction in electricity demand, the government decided to reduce the annual generation target under LRET from initial of 41 000 GWh to 33 000 GWh by 2030. Liable entities need to meet obligations under both the SRES (small-scale PV up to 100 kW, certificates granted for 15 years' worth of production) and LRET by acquiring and surrendering renewable energy certificates created from both large and small-scale renewable energy technologies.

Large-scale PV benefited from an auction (ACT programme) was set up in January 2012 for up to 40 MW.

The market take-off in Australia accelerated with the emergence of FiT programmes in several states to complement the national programmes. In general, incentives for PV, including FiTs, have been removed by State Governments and reduced by the Federal Government.

ASIA PACIFIC / CONTINUED

Self-Consumption

Self-consumption of electricity is allowed in all jurisdictions in Australia. Currently no additional taxes or grid-support costs must be paid by owners of residential PV systems (apart from costs directly associated with connection and metering of the PV system), although there is significant lobbying from utilities for additional charges to be levied on PV system owners.

In 2016, several local governments offered storage incentives and the demand response market is starting to expand from large industrial facilities to residential (homes with air-conditioners that can be operated at reduced power during times of peak demand).

The interest in on-site storage technologies has continued to increase with at least 6 750 installations of grid-connected batteries combined with PV systems totalling 42 MWh in 2016.

CHINA

FINAL ELECTRICITY CONSUMPTION 2016	5 920	TWh
HABITANTS 2016	1 379	MILLION
IRRADIATION	1 300	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	34 550	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	78 080	MW
PV PENETRATION	1,1	%

With 34,55 GW installed in 2016, the Chinese PV market has once again experienced a significant growth rate, from 15 GW in 2015. China has significantly beaten its initial official target of 18 GW set by the National Action Planning document in the beginning of 2016. With these installations, Chinese PV capacity confirmed its first rank with more than 78 GW at the end of 2016. Much more is due to come, showing that China takes it very seriously with RES development and intends to lead the deployment of GHG-free power sources.

The utility-scale segment continued to dominate the Chinese PV market with 30,3 GW installed in 2016. From 2013 until 2016, this segment contributed for a large part of all installations. Following the political willingness to develop the rooftop PV segment, it has received some interest and starts to develop, in both BAPV (PV on rooftops) and BIPV (PV integrated in the building envelope) segments. In 2013, 311 MW were installed, a number that increased to 2,1 GW in 2014, went down to 1,4 GW in 2015 and increased again in 2016 with 4,2 GW, showing the challenge of developing the distributed market. On the other side, the growth of centralized PV applications in the last 4 years has proven the ability of the FiT regime to develop PV markets rapidly.

Several schemes are incentivizing the development of PV in China. They aim at developing utility-scale PV through adequate schemes, rooftop PV in city areas and micro-grids and off-grid applications in the last un-electrified areas of the country. The following regulations were in place in 2016:

- In Dec. 2016, the National Energy Administration issued a "Solar power development plan during the thirteenth five-year plan period", setting the targets of no less than 105 GW for PV electricity, down from the 150 GW for PV installations previously set. Instead of the 170 TWh previously defined as a target by the year 2020, the levels were reduced to 105 TWh, with only 20 TWh for distributed PV, in line with the difficulties experienced in that segment. However, given the market development speed, a "guiding opinion" was issued in July 2017: PV installed capacity in China could then reach about 240 GW by 2020.
- A stable FiT scheme for utility-scale PV and rooftop PV drives the market development. It is entirely financed by a renewable energy surcharge paid by electricity consumers. Hence, in December 2016, the National Development and Reform Commission lowered the PV feed-in benchmark price, but letting it operational with late 2016 values until June 2017. Depending on the region, the price dropped in a range of 0,13 to 0,15 RMB/kWh to the FiT range between 0,65 and 0,85 RMB/kWh (down from 0,8 to 0,98 during the year 2016).
- To push prices down, China started to select bidders for "leading runner" PV projects in 2016. The bidding price was below the FiT price, with winning bids from 0,45 to 0,61 RMB/kWh. In parallel, NEA started to guide RES development with clear targets for each province. This RPS defines RES targets excluding hydropower by 2020.
- To ensure a faster development of distributed PV, the National Development and Reform Commission issued the "Notice on Perfection of Onshore Wind Power and PV Power Feed-in Benchmark Price Policy". This intends to allow distributed PV system owners to choose between a self-consumption model and a pure feed-in model, with limited possibilities to switch the remuneration model during the plant lifetime. Under self-consumption, the electricity injected into the grid is paid at the wholesale price (based on coal-fired power plants cost) plus 0,42 RMB/kWh. The self-consumed electricity also gets the same premium on the top of the retail electricity price.
- While the market is mostly concentrated in the traditional grid connected systems, other types of distributed PV have been developed such as hydro-PV hybrid plants, PV for agricultural greenhouses and ad-hoc PV installations for fisheries.
- The PV Poverty alleviation program allows to develop PV on roofs in 7 provinces and cities with no scale limitation in order to fight poverty. The installations reached 3,5 GW in 2016.
- In June 2015, the NEA, MIIT and CNCA jointly issued the "Opinions on Promoting Application of PV Products with Advanced Technologies and Industrial Upgrading", proposing the implementation of the "leading runner" (also known as "top runner), which included construction of PV power pilot bases with advanced technology and new technology pilot projects, requiring that all these projects apply products with advanced technologies. Under this program, 5,5 GW of high efficiency technologies have been deployed in 2016, supporting the PV industry in China to raise the technology bar in production.

Conclusions

China was the first PV market in the world for the fourth year in a row in 2016. Adequate policies are being put in place progressively and will allow the market to continue at a high level, driven by the climate change mitigation targets. Due to the fact that incentives for utility-scale PV plants were lowered with an installation deadline end of June 2017, the first half year of 2017 witnessed again a rapid increase in the construction of utility-scale PV plants. According to statistics of the NEA, in the half year alone, the newly added PV capacity already reached 24 GW, up 20% compared to 2016. PV contributed to 1,1 % of the total electricity consumption in 2016.

JAPAN

FINAL ELECTRICITY CONSUMPTION 2016	912	TWh
HABITANTS 2016	127	MILLION
IRRADIATION	1 050	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	7 890	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	42 041	MW
PV PENETRATION	4,5	%

In 2016 Japan registered 7,89 GW of new PV capacity, around 27% less than the installations that occured in 2015. The country has reached a total installed PV capacity of 42 GW, making it the second country in the world after China. Currently the majority of the capacities installed are grid-connected installations, while off-grid remains marginal. After having reached close to 11 GW, the market declined in 2016 due to policy changes and the need to better streamline PV development in the country.

With the start of the FiT programme in July 2012, the market for public, industrial application and utility-scale PV systems grew fast and brought rapidly Japan to the top of the global PV market. While Japan was one of the first market in the world in the first decade of this century, most installations took place after the implementation of the FiT program.

While the PV market in Japan developed in the traditional residential rooftop market, 2016 has seen again a major deployment of utility-scale plants: such systems represented to 3,2 GW in 2016. The residential market reached 766 MW in 2016, followed by the commercial segment with more than 2,4 GW and the industrial segment with close to 1,4 GW. BIPV represented 40 MW and off-grid applications 34 MW.

Feed-in Tariff

The FiT scheme remains the main driver for PV development in Japan. On 1st July 2012, the existing scheme that allowed purchasing excess PV production was replaced by this new FiT scheme, paid during 20 years for systems above 10 kW and 10 years for the excess electricity of PV systems below 10 kW. Its cost is shared among electricity consumers with some exceptions for electricity-intensive industries. This scheme, considered sometimes as quite generous, has triggered the important development of the Japanese PV seen in last three years.

In July 2016, the FiT was adjusted downwards with a certain impact on the PV market so far. However, the rapid price decline for PV modules indicates that the margins of installers and developers are also declining. Capital subsidies are also available for system not applying to the FiT, for commercial, industrial and utility-scale applications. A system of green certificates also exists for utility-scale plants but since it provides a lower remuneration than the FiT, it is not widely used for PV systems.

Self-Consumption

For prosumers' PV systems below 10 kW, the FiT programme is used to remunerate excess PV electricity. The self-consumed part of PV electricity is not incentivized. Self-consumed electricity is not subject to taxation and transmission & distribution charge. Self-consumption can benefit from subsidies in the commercial segment.

BIPV

BIPV has been included in demonstration programs that are currently running. The market for BIPV remains relatively small compared to the usual BAPV market and around 40 MW were installed in 2016. However, Japan is preparing the offtake of BIPV. NEDO started a study project named "study on BIPV" in order to collect information and identify issues for the commercialization of BIPV systems and in addition, METI runs a project on "International standardization of BIPV modules".

Storage

New demonstration projects to install storage batteries were started in various locations in 2016. They aim at managing the rapidly increasing penetration of PV. The "Demonstration Project for Improving the Balance of Power Supply and Demand with a Large-Capacity Storage Battery System" installs large-capacity storage batteries at grid substations in order to reduce reverse flows and better manage the impact of concentrated PV installations. Decentralized storage in residential PV applications is incentivized in order to increase the reliability of the power provision in case of emergency. Demonstration projects are also conducted for hydrogen storage.

Conclusion

The once second market for PV reached a high level in 2015 but with 7,89 GW it but experienced a significant decline in 2016. Hopefully the market will see a soft landing in the coming years. The appetite for electricity after the Great Earthquake in 2011 and the need for diversifying the electricity mix is expected to continue fueling PV development. Given the geographical configuration of the archipelago, it is highly probable that decentralized PV applications will constitute the majority of PV installations in some years. With numerous global PV players in all segments of the value chain, Japan will be one of the key players in tomorrow's energy world. PV contributed to 4,5 % of the total electricity consumption in 2016 and will be able to cover at least 4,82 % in 2017 based on the already installed capacity.

ASIA PACIFIC / CONTINUED

KOREA

FINAL ELECTRICITY CONSUMPTION 2016	484	TWh
HABITANTS 2016	51	MILLION
IRRADIATION	1 314	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	904	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	4 397	MW
PV PENETRATION	0,7	%

Since "The Renewable Portfolio Standards" (RPS) replaced the Korean FiT at the end of 2011, the Korean PV market followed an upward trend. In 2015, under this programme, the Korean PV market passed the GW mark with 1 011 MW compared to 926 MW in 2014. In 2016, 904 MW were installed, showing a relative stability for three years in the market, while the solar PV industry continued to grow.

At the end of 2016, the total installed capacity reached 4,4 GW, among which utility-scale PV plants accounted for around 88% of the total cumulative installed capacity. Distributed PV systems amounted to around 12% of the total cumulative capacity. The share of off-grid PV systems has continued to decrease and represents less than 1% of the total cumulative installed PV capacity. Centralized PV applications represented 804 MW in 2016 compared to only 100 MW of distributed applications. PV contributed to 0,74 % of the total electricity consumption in 2016 and will be able to cover at least 1,19 % in 2017.

Various incentives have been used to support PV development. In 2014, the "Fourth Basic Plan for the Promotion of Technological Development, Use, and Diffusion of New and Renewable Energy" based on the "Second National Energy Basic Plan" was issued. This plan includes many new subsidy measures including the development of "Eco-friendly Energy Towns," "Energy-independent Islands," and "PV Rental Programs."

The RPS scheme launched in 2012 will be active until 2024 and is expected to be the major driving force for PV installations in Korea, with improved details such as boosting the small scale installations (less than 100 kW size) by adjusting the REC and multipliers, and unifying the PV and non-PV markets.

RPS Programme

The RPS is a mandated requirement that the electricity utility business sources a portion of their electricity supplies from renewable energy. In Korea, electricity utility business companies (total 18 power producing companies) exceeding 500 MW are required to supply a total of 10% of their electricity from NRE (New and Renewable Energy) sources by 2024, starting from 2% in 2012. The PV set-aside requirement plan was shortened by one year in order to support the local PV industry. In 2016 alone, 800 MW were installed under this programme. With regard to the cumulative installed capacity, about 68% of the total PV installations in Korea were made under RPS scheme, to be compared with about 500 MW (about 14%) that were installed under the previous FiT programme which ended in 2011.

Home Subsidy Programme

This programme was launched in 2004, and merged with the existing 100 000 rooftop PV system installation programme. It aims at the construction of one million green homes utilizing PV as well as solar thermal, geothermal, small-size wind, fuel cells and bio-energy until 2020. In general, single-family houses and multi-family houses including apartments can benefit from this programme. The Government provides 60% of the initial PV system cost for single-family and private multi-family houses, and 100% for public multi-family rental houses. The maximum PV capacity allowed for a household is 3 kW. Only some dozens of MW were installed under this programme in 2016.

Building Subsidy Programme

The Government supports up to 50% of installation cost for PV systems (below 50 kW) in buildings excluding homes. In addition, the Government supports 80% of initial cost for special purpose demonstration and pre-planned systems in order to help the developed technologies and systems to diffuse into the market. Various grid-connected PV systems were installed in schools, public facilities, welfare facilities, as well as universities.

Regional Deployment Subsidy Programme

The government supports 50% of the installation cost for NRE (including PV) systems owned or operated by local authorities. In 2016, 14 MW was installed under this programme.

Public Building Obligation Programme

The new buildings of public institutions, the floor area of which exceeds 1 000 square meters, are obliged by law to use more than 15% (in 2016) of their total expected energy from newly installed renewable energy resource systems. Public institutions include state administrative bodies, local autonomous entities, and state-run companies. The building energy mandate percentage will increase up to 30% by 2020. In 2016, 33 MW was installed under this programme.

PV Rental Programme

Household owners who are using more than 350 kWh electricity can apply for this program. Owners pay a PV system rental fee (maximum monthly 70 000 KRW which is on the average less than 80% of the electricity bill) for a minimum of 7 years and can use the PV system with no initial investment and no maintenance cost for the rental period. PV rental companies recover the investment by earning PV rental fees and selling the REP (Renewable Energy Point) having no multiplier. In 2016, 8,6 MW (8 796 households) were installed under this programme.

Convergence and Integration Subsidy Programme for NRE

This programme is designed to help diffuse the NRE into socially disadvantaged and vulnerable regions and classes such as islands, remote areas (not connected to the grid), long-term rental housing district, etc. Local adaptability is one of the most important criteria, thus the convergence between various NRE resources (PV, wind, electricity and heat) and the complex between areas (home, business and public) are primarily considered to benefit from this programme. In 2016. 5 MW was installed under this programme.

MALAYSIA

FINAL ELECTRICITY CONSUMPTION 2016	141	TWh
HABITANTS 2016	31	MILLION
IRRADIATION	1 200	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	72	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	336	MW
PV PENETRATION	0,3	%

The Malaysian market remains small compared to some key markets in Asia but implements policies that should pave the way to renewable energy development. Due to policy changes, the PV market increased from 26,8 MW in 2015 to 71,8 MW in 2016. The total installed capacity in Malaysia topped 335,77 MW at the end of 2016. As of the end of December 2016, the Sustainable Energy Development Authority Malaysia approved a total of 3 794 new applications (equivalent to 101,6 MW). Of the newly installed capacity in 2016, the BAPV applications were 30,9 MW, BIPV 33,12 MW, ground mounted 7,5 MW and floating solar 0,27 MW.

The National Renewable Energy Policy and Action Plan (NREPAP) provides long-term goals and commitment to deploy renewable energy resources in Malaysia. The objectives of NREPAP include not only the growth of RES in the electricity mix but also reasonable costs and industry development.

The Sustainable Energy Development Authority Malaysia or SEDA Malaysia was established on 1st September 2011 with the important responsibility to implement and administer the FiT mechanism.

The FiT Programme is financed by a Renewable Energy Fund (RE Fund) funded by electricity consumers via a 1,6% collection imposed on the consumers' monthly electricity bills. Domestic consumers with a consumption no more than 300 kWh per month are exempted from contributing to the fund. Due to the limited amount of the RE Fund, the FiT is designed with a cap for each technology. On 29 December 2016, new degression rates were announced. The degression rates for installed PV capacities of up to 1 MW remained unchanged whereas for PV systems with capacities greater than 1 MW and up to 30 MW, the rate was revised from 20% to 15%. The decrease rate for bonus FiT rate for use as in building or building structures were reduced from 20% to 10%.

In October 2015, the Prime Minister of Malaysia announced a net-metering scheme with a 100 MW quota per year for PV installation starting 1st November 2016, that could accelerate the development of the PV market in Malaysia. The total PV quota allocated under the net metering is 500 MW over a period of five years.

THAILAND

FINAL ELECTRICITY CONSUMPTION 2016	181	TWh
HABITANTS 2016	69	MILLION
IRRADIATION	1 355	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	1 027	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	2 446	MW
PV PENETRATION	1,8	%

The PV market increased significantly in Thailand with 1,03 GW that have been installed in 2016 compared to 121 MW in 2015 and 475 MW in 2014. The large majority of installations developed in 2016 were in the utility-scale segment, while less than 1 MW of new off-grid systems were officially deployed. In Thailand, at the end of 2016, the cumulative grid-connected PV capacity reached 2,41 GW and 33,80 MW of off-grid PV applications.

According to the latest Alternative Energy Development Plan 2016-2036, Thailand aims to reach 6 GW of total installed PV capacity in the next 20 years, an objective that looks achievable easily given the past development trends.

The Feed-in Tariff scheme continued to drive installations during the year 2016. Until April, the newly installed capacity resulted of the extension of the feed-in tariff (for ground-mounted PV power plants) from December 2015 to April 2016. At the end of the year, the driver shifted towards the program for governmental agencies and agricultural cooperatives for ground-mounted systems. In September, the National Energy Policy Committee (NEPC) revised the FiT rate down from 5.66 THB/kWh to 4.12 THB/kWh for the PV plant below 10 MW (or VSPP plants, for Very Small Power Plants) (≤10 MW).

In addition, PV for rural electrification can be incentivized up to 100% and cover schools, community centers, national parks, military installations and hospitals. However, the installed capacities remain at a very low level, with some kW in each case.

To support distributed PV for rooftops, the PV Pilot project for self-consumption or "Quick Win" program has been implemented. Its target has been set at 100 MW for households and buildings or factories with electricity consumption during day time. Applicants are allowed to feed in electricity into to the grid without any compensation from government, in order to promote local self-consumption.

The PV rooftop pilot program was released in August with the objective to identify barriers, grid challenges, and the impact on all electricity system stakeholders. It received 358 applications totaling 32,72 MW that were awarded a contract under this program. These systems should be installed and connected to the grid by 2017. The result will be used to improve policies and measures in future PV rooftop policies.

PV investors are offered the exemption in corporate tax and import duty for machinery if the capital investment is above a certain level. In addition, a program has been implemented to support the deployment of PV as an energy efficiency solution. It aims at supporting factories and buildings to reduce their electricity consumption.

With these schemes, Thailand aims at continuing to support the expansion of the deployment of grid-connected PV in the rooftop segments, after a rapid start in the utility-scale segment, continuing to lead PV development in Southeast Asia.

ASIA PACIFIC / CONTINUED

OTHER COUNTRIES

2016 has seen PV developing in more Asian countries in such a way that Asia is now the very first region in terms of new PV installations. Several countries present interesting features that are described below.

India, with more than one billion inhabitants has been experiencing severe electricity shortages for years. The Indian market jumped to 4,1 GW in 2016 from 779 MW in 2014 and 2 GW in 2015, powered by various incentives in different states. The PV market in India is driven by a mix of national targets and support schemes at various legislative levels. The Jawaharlal Nehru National Solar Mission aims to install 20 GW of grid-connected PV systems by 2022 and an additional 2 GW of off-grid systems, including 20 million solar lights. Some states have announced policies targeting large shares of solar photovoltaic installations over the coming years. Finally, 2 GW of off-grid PV systems should have been installed by 2017. However, in 2014 a brand-new target of 100 GW was unveiled: 60 GW of centralized PV and 40 GW of rooftop PV. The support of the central government in India for PV is now obvious and will lead in the coming years to a significant increase of installations. Much more installations are expected in the years to come and already in 2017 to meet the official ambitions. India has also initiated the launch of the International Solar alliance, aiming at accelerating the development of solar in emerging countries. This ISA has been announced during the COP21 in Paris together with France.

In 2016 Taiwan installed about 369 MW mostly as grid-connected rooftop installations after having installed 227 MW in 2015 and 223 MW in 2014. The total installed capacity at end of 2016 is estimated to be around 1,2 GW. The market is supported by a FiT scheme guaranteed for 20 years and managed by the Bureau of Energy, Ministry of Economic Affairs. This scheme is part of the Renewable Energy Development Act (REDA) passed in 2009 that drove the development of PV in Taiwan. The initial generous FiT was combined with capital subsidy. It has later been reduced and now applies with different tariffs to rooftops and ground-mounted systems. Larger systems and ground based systems have to be approved in a competitive bidding process based on the lowest FiT offered. Property owners can receive an additional capital subsidy. It is intended to favor small scale rooftops at the expense of larger systems, in particular ground based installations. So far, agricultural facilities and commercial rooftops have led the market. The country targets 2,1 GW in 2020 and 6,2 GW in 2030 (3 GW on rooftops, 3,2 GW for utility-scale PV). In 2012, Taiwan launched the “Million Roof Solar Project” aimed at developing the PV market in the country,with the support of municipalities. The authorization process has been simplified in 2012, in order to facilitate the deployment of PV systems and will most probably ease the development of PV within the official targets as the progress of the market has shown.

The Government of Bangladesh has been emphasizing the development of solar home systems (SHS), since about half of the population has no access to electricity. Under the Bangladesh zero-interest loan from the World Bank Group as well as support from a range of other donors, the government is promoting incentive schemes to encourage entrepreneurs who wish to start PV actions; at present led by the Infrastructure Development Company Ltd. (IDCOL) working with about 40 NGOs. Thanks to the decrease in prices of the systems and a well-conceived micro-credit scheme (15% of the 300 USD cost is paid directly by the owner and the rest is financed through a loan), off-grid PV deployment exploded in recent years. The number of systems in operation is estimated above 4 million SHS in the beginning of 2016. More are expected after some financing from the World Bank, up to 6 million by the end of 2017. The average size of the system is around 50-60 W; for lighting, TV connections and mobile phone charging. Local industries are involved in the process and could replicate this in other countries. IDCOL also targets of 1 500 irrigation PV pumps by 2018. The government started to introduce more PV power by setting up a Solar Energy Program and is planning to introduce more than 1 GW of solar energy in the coming years. Several announcements have been made, which remains to become concrete.

The Philippines have installed 759 MW in 2016, raising the total installed capacity to 900 MW and much more is foreseen in the coming years. As of 31 December 2016, there were 124 grid-connected projects in the pipeline that had been awarded under the country’s renewable energy (RE) law, totalling 4 016 MW. Meanwhile, there were 13 self-consumption projects totalling 2,4 MW also awarded. Total self-consumption capacity stood at 1,9 MW at the end of 2016.

Other Asian countries are seeing some progress in the development of PV. Pakistan installed several hundreds of MW which followed the approval of 793 MW of solar plants. A FiT has been introduced for utility-scale PV in 2014. It is estimated that at least 500 MW have been installed so far. Brunei has announced that a FiT policy should be put in place over the next 18-24 months.

In 2014, Indonesia put in place a solar policy which started already in 2013. Under this regulation, solar photovoltaic power is bought based on the capacity quota offered through online public auction by the Directorate General of New Renewable Energy and Energy Conservation. The plant that wins the auction will sign a power purchase agreement with the National Electric Company at the price determined by the regulation. However, so far only 20 MW were installed in 2014 and in 2016 the first utility-scale plants were connected to the grid. In early 2016 the government announced a 5 GW plan to develop PV in the country.

Myanmar has signed a memorandum for building several large-scale plants and 220 MW were foreseen at the end of 2016. In Singapore, the total PV installed capacity was 30 MW at the end of 2016 with a target of 350 MW in 2020. Uzbekistan has the intention to install 2 GW of PV plants and 300 MW of utility-scale plants were being developed at the end of 2016. In Kazakhstan, the government aims at installing 700 MW and has established a FiT program in 2014. In Nepal, the Electricity Agency planned to develop PV power plants totalling 325 MW by 2017.

In Vietnam, 800 MW have been allocated and should be built before 2020 and a national solar plan is being developed with ambitious targets until 2030.

EUROPE

Europe has led PV development for almost a decade and represented more than 70% of the global cumulative PV market until 2012. Since 2013, European PV installations went down while there has been rapid growth in the rest of the world. Europe accounted for only 17% of the global PV market with 6,5 GW in 2016. European countries installed 104 GW of cumulative PV capacity by the end of 2016, still the largest capacity globally, for the last year. It is important to distinguish the European Union and its countries, which benefit from a common regulatory framework from part of the energy market, and other European countries which have their own energy regulations and are not part of the European Union.

AUSTRIA

FINAL ELECTRICITY CONSUMPTION 2016	59	TWh
HABITANTS 2016	9	MILLION
IRRADIATION	1 026	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	171	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	1 108	MW
PV PENETRATION	1,88	%

Austria's support for PV relies on a mix of capped FiT and investment grants. Due to a cap on the tariffs, the development of PV in Austria remained constrained at a relatively low level with a market below 100 MW until 2012. After 363 MW in 2013, the market appears to enter a stage of stable development, with around 150 MW in the last three years. With 155 MW-AC installed in 2016 (around 171 MW-DC given the high share of residential installations), the market is concentrated in the distributed segment, with only 6,7 MW-AC (around 8 MW-DC) of ground-mounted installations. BIPV installations represented around 2 MW in 2016. Off-grid development amounted to around 1 MW. Off-grid contribute in total for around 6 MW out of 1,1 GW as Austria cumulative market end of 2016.

Systems below 5 kWp are incentivized through a financial incentive. Additional investment subsidy is available for BIPV installations. Above 5 kWp, the Green Electricity Act provides a FiT that was reduced in 2014. The FiT is guaranteed during 13 years and financed by a contribution of electricity consumers. Some financial grants can be added for specific buildings. In addition to federal incentives, some provinces are providing additional incentives through investment subsidies.

Self-consumption is allowed for all systems. A self-consumption fee of 1,5 EURcent/kWh has to be paid if the self-consumption of PV electricity is higher than 25 000 kWh per year.

Rural electrification in remote areas not connected to the grid is incentivized through an investment subsidy up to 35% of the cost.

Since 2016, more and more provinces provide an investment subsidy to support the installation of decentralized electricity storage systems in combination with PV. For example, Vienna provides a limited incentive of 500 EUR/kWh while Burgenland has a non-refundable rebate of 275 EUR/kWh for storages up to 5 kWh. The highest incentive reached up to 600 EUR/kWh with a limit at 7.5 kWh.

At least two utilities provide the possibility to invest in PV systems without installing them directly. Such virtual investment schemes allow the deployment of PV financed by private electricity consumers without any physical link. Virtual storage options have been also proposed to PV consumers by some utilities, showing that utilities are considering PV seriously in Austria.

BELGIUM

FINAL ELECTRICITY CONSUMPTION 2016	84	TWh
HABITANTS 2016	11	MILLION
IRRADIATION	990	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	173	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	3 423	MW
PV PENETRATION	4	%

Belgium is a complex case with different PV incentives in the three regions that compose the country, but an electricity market that covers the entire country. Organized in a federation of regions (Flanders, Wallonia and Brussels region), the country set up regulations that are sometimes regional, sometimes national.

Despite this organization, all three regions selected an RPS system, with quotas for RES that utilities have to provide, and set up three different trading systems for green certificates. In addition, the price of green certificates is guaranteed by the national TSO that charges the cost to electricity consumers.

Flanders started to develop first and has installed about 2,57 GW of PV systems. In Wallonia, the market started with a two-years delay and remains largely concentrated in the residential and small commercial segments with around 914 MW at the end of 2016. In Flanders, large rooftops and commercial applications have developed since 2009. 170 MW were installed in the country in 2016, a strong increase in comparison with the 107 MW installed in 2015. Belgium now runs 3,5 GW of PV systems.

For small rooftop installations below 5 kW or 10 kW, a net-metering system exists across the country. Until 2010, further grants were paid in addition to other support schemes while the tax rebates were cancelled in November 2011.

In Flanders, a prosumer fee (95 EUR/KW) was introduced in July 2015 for all small PV systems (below 10 kW). And despite this, the market remains quite active. This fee enables DSOs to charge for the cost of grid use by PV owners, without changing the system of net metering. It gives a simple payback time around 15 years for a new PV installation. This success is mainly due to the positive communication action made in Flanders to promote PV with a simple message: "You earn more by investing your savings into PV than by leaving it on your bank account."

In Wallonia, the "Qualiwatt" support plan for small systems (≤10 kW) introduced in 2014 has had a relative success in 2016. It improved compared to 2015 but the maximum allowed quota for installations was not reached (~5 300 out of 12 000). The Qualiwatt program is an up-front incentive paid over five years and calculated to reach a payback time of 8 years (5 % IRR for a 3 kWp

EUROPE / CONTINUED

installation after 20 years). Besides the financial aspects, this new plan also introduces strong quality criteria on the equipment (European norms, factory inspection), the installer (RESCERT training) and the installation (standard conformity declaration, standard contract) to increase the reliability and confidence. Anyway the climate for PV remains negative due the legacy of the first uncontrolled years of development and the lack of awareness of most policymakers about the need for a rapid energy transition.

Brussels will be the first region to replace the yearly net-metering system for small systems (< 5 kW) by a self-consumption scheme by 2018, but the details of the scheme are not known yet.

Larger systems benefit from a self-consumption scheme and from an additional green certificate support scheme. For large systems in Wallonia, 2016 was a good year. Since 2015, a system of GC reservation controls the development of the market. The maximum has been reached with more than 60 MW reserved in 2016.

In general, the Belgian market is transitioning from an incentive-driven market to a self-consumption-driven market. This transition will imply a revision of net-metering policies and possibly new forms of incentives in the coming years. The major risk lies in the willingness of several policymakers and grid operators to tax prosumers, a counterproductive policy that has so far limited the confidence in PV.

DENMARK

FINAL ELECTRICITY CONSUMPTION 2016	30,5	TWh
HABITANTS 2016	6	MILLION
IRRADIATION	925	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	71	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	858	MW
PV PENETRATION	2,8	%

71 MW of PV systems were installed in Denmark in 2016, with 20 MW in the distributed segment and 51 MW of utility-scale plants. The development of PV in Denmark has experienced difficulties, following a rapid start: by the end of 2011, only 17 MW were installed in Denmark. Grid-connected installations represented the majority, and some off-grid installations were found for instance in Greenland for stand-alone systems in the telecommunication network and remote signaling. That net-metering system set by law for private households and institutions led to a rapid market expansion in 2012 that continued partially in 2013 before the market collapsed to 42 MW in 2014. The PV market then increased significantly in 2015 with 181 MW installed, thanks mainly to utility-scale applications which represented 131 MW, and a rather stable rooftop market. Off-grid remains anecdotic with 0,4 MW installed in 2016. In total 858 MW of PV are producing electricity in the country at the end of 2016.

Back in November 2012, the government reacted to the high level of market development and modified the net-metering law. While the compensation between PV electricity production and local electricity consumption occurred during the entire year, the new regulation allows compensation to take place during only one hour. This change reduced the number of installations from 2013 onwards. Then the FiT system was suspended in May 2015 due to its success. All technology specific incentives are expected to be completely phased-out in 2017. Self-consumption replaced it as the main driver for distributed PV applications, especially in the residential and commercial segments, but again at a lower level.

At the end of 2015, Denmark launched a one-off pilot tender scheme of 20 MW for utility-scale ground-mounted PV systems up to 2,3 MW. A particularity from that tendering system is that it is open to German bids, which implies that PV installations in Germany could compete in the tender and the other way around. The utility-scale development that has been seen in 2015 was the consequence of an interpretation of the existing EU legislation: Five utility-scale PV farms ranging from 9 to 70 MW were registered in December 2015. All were built in subunits of 400 kW driven by the 2015 FiT regulations. This continued in 2016 at a lower level.

There are presently no direct support measures for BIPV. However, the building codes promote the use of BIPV in new buildings and at major refurbishments.

Finally, the debate about the legality of the scheme supporting PV in Denmark has been questioned by European authorities, under the excuse that they could oppose state aid regulation, which was pushing the Danish government at that time to move the budget to support PV to the state budget. This example shows how pro-PV regulations could become a complex regulatory issue in today's Europe, with the need to choose between the energy transition and free-market regulations. In addition, with high retail electricity prices due to taxes, self-consumption of PV electricity is seen as a threat to the tax income for the government and raises a significant opposition despites its competitiveness.

EUROPEAN UNION

In addition to all measures existing in Member States, the European Union has set up various legislative measures that aim at supporting the development of renewable energy sources in Europe.

The most well-known measure is the Renewable Energy Directive that imposes all countries to achieve a given share of renewable energy in their mixes so as to reach an overall 20% share of renewable energy in the energy mix at the European level. Directive 2009/28/EC set mandatory targets for the Member States, but let them decide about the way to achieve their binding 2020 targets, PV targets were set up in various ways. In October 2014, the European Council adopted an EU targets until 2030 for renewable energy development in the framework of its climate change policies. It set a new target of at least 27% of renewable energy sources in the energy mix, together with energy savings targets and GHG emissions. However, different to the 2009 Directive no mandatory targets have been proposed for the individual Member States and it is unlikely that the new directive under preparation will do so, even if the target could be revised upwards, possible to 35% in 2018.

Besides the Renewable Energy Directive, the so-called Energy Performance of Building Directive defines a regulatory framework for energy performance in buildings and paves the way for near-zero and positive energy buildings.

The grid development is not forgotten. Dedicated funding schemes (TEN-E) have been created to facilitate investments in specific interconnections, while several network codes (e.g. grid connection codes) are currently being prepared. This will have a clear impact on PV systems generators when finally approved and adopted.

In addition, the question of the future of electricity markets is central in all electricity sector's discussions. The growing share of renewable energy suggests to rethink the way the electricity market in Europe is organized in order to accompany the energy transition in a sustainable way for new and incumbent players. Meanwhile, it has been made rather clear that the huge losses of several utilities in the last years can rather be attributed to cheap lignite pushing gas out of the market and other similar elements rather than the impact of a few percent of PV electricity. While the role of PV was sometimes questioned due to the observed price decrease during the midday peak that is attributed to PV power production, it is absolutely not obvious whether this decrease during a limited number of hours every year really has an impact on the profitability of traditional utilities. In parallel to this, it is important to mention the failure of the Emission Trading Scheme (ETS), that aimed at putting a carbon price which would have normally pushed coal power plants out of the market. However due to the inability of the scheme to maintain a fair carbon price, coal power plants were not decommissioned. More than 100 GW of gas power plants that were built in the last decade in anticipation of the decommissioning of coal power plants finally caused a huge overcapacity in conventional electricity production. In that respect, with more than a decade of rapid increase of production capacities and electricity consumption stagnation, several utilities suffer from reduced operating hours and lower revenues. The demand has hardly increased in the last decade in Europe.

Fearing for generation adequacy issues in the coming years due to gas power plants decommissioning, some Member States as well as companies are pushing for Capacity Remuneration Mechanisms in order to maintain the least competitive gas plants on the market. While the impact of PV on this remains to be proven with certainty, the future of the electricity markets in Europe will be at the cornerstone of the development of PV.

The debate about the future of renewables continued in 2016 with the revision of the state-aid rules, through which the European Commission pushed Member States to shift incentives from FiTs to more market based instruments, including possible technology-neutral tenders. This recommendation has already been followed by several member states including Germany or Spain. At the end of 2016, the proposal called "Clean Energy for All Europeans" paved the way for a development of self-consumption under fair rules, together with market improvements and rules for decentralized storage. While the package hasn't yet been approved, it highlights a change in mentalities going in the right direction.

Finally, in order to answer complaints from European manufacturers, the European Commission adopted final measures in the solar trade case with China in December 2013 which were still applicable at the end of 2016. This decision confirms the imposition of anti-dumping and countervailing duties on imports into the European Union of crystalline silicon photovoltaic modules and cells originating from China. These duties, which are valid for a period of two years, were not applied retroactively.

Meanwhile, the acceptance of the undertaking offer submitted by China to limit the volumes and to set a threshold for prices has been accepted. The companies covered by this undertaking will be exempted from the general imposition of duties but will have to comply with minimum prices for modules and cells sold in Europe, within a certain volume. Following the decline of PV modules costs and prices, some companies decided to go out of the agreement and to enter the European PV market by paying the anti-dumping charges : the low prices on the market should continue to push additional companies to exit the agreement.

The Energy Performance in Buildings Directive (EPBD) will enter into force in 2020 and might become an important driver of PV development in the building sector by pushing PV as the main possibility to reduce the net energy consumption in buildings after energy efficiency. While the final effect will have to be scrutinized after 2020, it represents a major opportunity for the building sector and PV to work together.

FINLAND

FINAL ELECTRICITY CONSUMPTION 2016	85	TWh
HABITANTS 2016	6	MILLION
IRRADIATION	838	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	17,4	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	37,4	MW
PV PENETRATION	0,0	%

The total capacity of grid-connected PV plants is estimated at around 37 MW. However, the market in 2016 witnessed visible signs that the segment of grid-connected rooftop PV systems is starting to grow in commercial and residential scales with 17 MW installed. There has been no utility-scale PV plants in Finland so far. The off-grid PV market in Finland started in the 1980's and has focused mainly on summer cottages and mobile applications. These systems are generally quite small size, typically less than 200 W.

There are some financial support schemes available for PV installations. The Ministry of Economic Affairs and Employment grants investment support for the energy production. This energy support is particularly intended for promoting the introduction and market launch of new energy technology. So far, the Ministry has granted a 25% investment subsidy of the total costs of grid-connected PV projects. During the year 2016, 6 MEUR was granted for 17 MW of new PV capacity . The decision for the investment subsidy is made case-by-case based on application.

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Only companies, communities and other organizations are eligible for the support. For the agricultural sector an investment subsidy for renewable energy production from the Agency of Rural Affairs is available as well. The subsidy covers 40% of the total investment. However, only the portion of the investment used in agricultural production is taken into account.

Self-consumption of PV electricity is allowed in Finland. However, the current net-metering scheme is real-time, and the majority of installed electricity meters do not net-meter between phases. The hourly-based net-metering for individual consumers is under discussion, and will possibly be implemented. In residential and commercial scales both the consumption and the generation of electricity is metered with the same energy meter owned by the DSO. Several energy companies offer two-way electricity (buying and selling) contracts for prosumers. Electricity generation below 100 kVA is exempted from the payment of electricity tax. The tax exemption is also valid for larger plants than 100 kVA if their annual electricity generation is below 800 MWh. The owning of a PV system is not regarded as a business activity in Finland. Individuals can produce electricity for their own household use without paying taxes. For individual persons, the income from the surplus electricity sales is considered as a personal income. However, individuals can subtract the depreciation and yearly system maintenance cost from the sales income. As a result in most cases the additional income from a rooftop PV system will not lead to additional taxes. Individuals can get a tax credit for the installation of the PV system on an existing building. The amount covers 45% of the total work cost including taxes. The maximum tax credit for a person is 2 400 EUR/year and it is subtracted directly from the amount of taxes that have to be paid.

With these incentives, Finland has started to see some PV development which should continue in the coming years.

FRANCE

FINAL ELECTRICITY CONSUMPTION 2016	483	TWh
HABITANTS 2016	67	MILLION
IRRADIATION	1 160	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	559	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	7 164	MW
PV PENETRATION	1,7	%

The political decision was taken to maintain the market around 1 GW per year in the last years and to increase it in the coming years, up to 2 GW a year. However, unexpected long grid connection delays have drastically slowed down the capacity increase.

The newly added capacity in France decreased slightly to 559 MW in 2016 compared with 894 MW in 2015, after having reached 1 120 MW in 2012 and 654 MW in 2013; a number that should increase in the coming years. Indeed, following COP21, France has put an effort in boosting its solar market by revising the national PV installed capacity target to 10,2 GW in 2018 and between 18,2 to 20,2 GW in 2023.

The rooftop market below 250 kW represented around 37% whereas systems above 250 kW, both rooftop and utility-scale, represented around 63% of added capacity in 2016. The total installed capacity reached 7,1 GW by the end of 2016, including overseas departments (367 MW). In total utility-scale PV systems represented slightly less than 2,6 GW at the end of 2016, with a 300 MW plant installed in 2016. Off-grid installations in 2016 were around 0,5 MW while the total off-grid installed capacity was close to 31 MW.

The national support measures currently implemented in France are guaranteed feed-in-tariffs (paid for by electricity consumers) and tender procedures for systems above 100 kW.

One specific element of the French regulatory framework lies in the priority given to supporting BIPV systems over conventional BAPV systems. In May 2016, feed-in tariffs were limited to systems under 100 kW installed on buildings, but with a continued support for BIPV. The support to BIPV explains the relatively high costs of support schemes in France. The income tax credit for private BIPV roof owners was phased out on 1 January 2014, but the material costs still benefit from a reduced 10 % VAT rate. In 2016, the residential hybrid system PV-T has become eligible to the CITE energy transition tax credit.

Projects over 100 kW can respond to calls for tenders. A new calendar for new tenders with capacity of 4 350 MW between 2016 and 2019 was published in 2016. So far, the low retail prices for electricity have been a challenge especially for the development of self-consumption in France. Hence, some regions are promoting self-consumption projects through their calls for proposals. New call for tenders will be dedicated to self-consumption from 2016 onwards.

From 2017, for systems over 0,5 MW, electricity generated will be sold directly on the electricity spot market, with an additional remuneration to meet tendered rates.

Overseas departments and territories of France are mainly composed of islands with different grid connection rules than the mainland in order to cope with the smaller grids, and capacity penetration limits.

GERMANY

FINAL ELECTRICITY CONSUMPTION 2016	548	TWh
HABITANTS 2016	83	MILLION
IRRADIATION	942	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	1 476	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	41 186	MW
PV PENETRATION	6,4	%

With three years in a row (2010 - 2012) above 7 GW of PV systems connected to the grid, Germany used to be the most iconic PV market for many years. This was achieved thanks to a combination of several elements:

- A long term stability of support schemes;

- The confidence of investors;
- The appetite of residential, commercial and industrial building owners for PV.

From 2013 to 2016, the PV market went down to 3,3 GW (2013) then around 1.5 GW (2015 and 2016), below the political will to frame the development of PV within a 2,4-2,6 GW range each year. This results into a total installed PV capacity of 41,2 GW connected to the electricity grid at the end of 2016. Regarding the total installed capacity, 2016 was also the year that saw Japan overtaking Germany and putting itself in the second place. This shows the relative decline of the market that used to power the entire PV sector at the beginning of the decade.

Breathing Feed-in Tariff

The EEG law has introduced the FiT idea and has continued to promote it partially. It introduces a FiT for PV electricity that is mutualised in the electricity bill of electricity consumers. Exemption is applied to energy-intensive industries, a situation that was challenged by the European Commission in 2013. With the fast price decrease of PV, Germany introduced the "Breathing FiT" concept in 2009: a method allowing the level of FiTs to decline according to the market evolution. Depending on the deviation from a defined threshold value, the degression of the FiT will be accelerated or decelerated. During the years, threshold value and degression rates have been changed several times, especially the period between updates and the calculation period for the actual market size have been reduced to avoid market booms (the biggest one came in December 2011 with 3 GW in one single month). The latest change was put in place 2017, when the threshold was changed from a 2,4-2,6 GW corridor to a fixed value of 2,5 GW: 1,9 GW BAPV/BIPV + 0,6 GW ground mounted. During the year 2016, no reduction of the FiT was executed due to the low market level.

Since September 2012, Germany started to limit the size of installations that can profit from the FiT. Since 2017 only systems below 100 kWp can profit from a classic FiT, while systems up to 1 MW on residential buildings and up to 10 MW on non-residential buildings have the possibility to benefit from the so called "market integration model" (see below).

Self-Consumption

Until 2012, a self-consumption premium that was paid above the retail electricity price was the main incentive to self-consume electricity rather than injecting it into the grid. On the 1st April 2012, the premium was cancelled when FiT levels went below the retail electricity prices. With the same idea, for systems between 10 kW and 1 MW, the grid injection is capped to 70% of the maximum system power in order to force self-consumption. If the remaining 30% has to be injected anyway, a low market price is paid instead of the FiT.

Prosumers have to pay 40% of the surcharge for renewable electricity for the self-consumed electricity for systems above 10 kW. In 2017 this surcharge amounts to 6,88 EURct on every kWh consumed from the grid.

A programme of incentives for storage units was introduced 1st May 2013, which aims at increasing self-consumption and developing PV with battery storage in Germany. A 25 MEUR market stimulation programme has been introduced to boost the installation of local stationary storage systems in conjunction with small PV systems (< 30 kWp). Within the framework of this storage support programme around 20 000 decentralized local storage systems were funded by the end of 2016. During 2016, around 800 local storage systems for existing PV systems were funded with 7 MEUR. 5 668 of the newly installed funded PV systems were build with local storage. A continuation of this programme is planned until the end of 2018.

Market Integration Model

In contrast to self-consumption incentives, Germany pushes PV producers to sell electricity on the electricity market through a "market premium". The producer can decide to sell its electricity on the market during a period of time instead of getting the fixed tariff and receives an additional premium on the top of the market price. The producer can go back and forth to the FiT system or the market as often as necessary. New PV installations above 100 kWp are forced to access the electricity.

To take part in the "market integration model" ground mounted systems have to run a tendering procedure. Three calls with a total capacity of 600 MW are executed every year. The price level was reduced from call to call: from 0,0917 EUR/kWh in the pilot auction 2015 it declined continuously: The most recent price obtained from the sixth solar auction in December 2016 was 0,069 EUR/kWh. 2017 auctions have contributed to even lower prices.

Grid Integration

Due to the high penetration of PV in some regions of Germany, new grid integration regulations were introduced. The most notable ones are:

- The frequency disconnection settings of inverters (in the past set at 50,2 Hz) has been changed to avoid a cascade disconnection of all PV systems in case of frequency deviation.
- Peak shaving at 70% of the maximum power output (systems below 30 kW) that is not remotely controlled by the grid operator.

ITALY

FINAL ELECTRICITY CONSUMPTION 2016	308	TWh
HABITANTS 2016	61	MILLION
IRRADIATION	1 158	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	382	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	19 297	MW
PV PENETRATION	7,2	%

Italy in 2016 installed 382 MW compared to a lower 300 MW in 2015. Grid-connected installed capacity reached 19 283 MW with in addition 14 MW of off-grid plants. The growth of the last few years lowered compared to past years because of the end of incentive scheme in 2013.

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Italy developed different incentive mechanisms. The first one was the "10 000 PV roofs" that was implemented in the early 2000, followed in July 2005 by a Feed-in Tariff (Feed-in Premium until 2012) system, the so-called "Conto Energia". This scheme was regulated with four successive ministerial decrees that further exploited the already existing mechanism of net-metering and a real time self-consumption.

The cost of the incentive is covered by a component of the electricity tariff structure paid by all final consumers (the financial cap set by FiT was 6,7 BEUR in terms of yearly payments).

In 2009 Italy switched from the net-metering mechanism to the so-called "Scambio Sul Posto" (SSP) for systems below 200 kW (500 kW for plants installed starting from 2016). The SSP is a net-billing scheme, in which electricity fed into the grid is remunerated through an "energy quota" based on electricity market prices and a "service quota" depending on grid services costs (transport, distribution, metering and other extra charges). In case the producer does not want to apply for the SSP, electricity market prices are applied for the electricity injected into the grid. Out of 382 MW installed in 2016, almost all plants are under the SSP net-billing scheme.

Tax credit (available only for small size plants up to 20 kW), together with the net-billing scheme, are the remaining measures to support the PV market; in addition, in the frame of a specific law related to urban planning, the opportunity to increase the volume of existing buildings in case of RES plants is confirmed.

Residential installations represented 40% of the Italian PV market in 2016; utility scale market is on a slightly recovering trend, thanks also to the sharp drop of the PV module costs.

Regarding storage, tax credit measures are foreseen, but so far storage has been installed in few residential PV plants, integrated with the inverter in order to achieve a better performance of the installed system.

NETHERLANDS

FINAL ELECTRICITY CONSUMPTION 2016	114	TWh
HABITANTS 2016	17	MILLION
IRRADIATION	950	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	525	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	2 084	MW
PV PENETRATION	1,7	%

Until 2003, the Dutch PV market developed thanks to an investment grant that was extremely successful. Due to budget reallocation, the grant was cancelled and the market went down to a low level. From 2008-2009 the government introduced a new FiT programme with a financial cap. This revitalized the market until the end of the programme in 2010. Since 2011, the main incentive in the Netherlands is a net-metering scheme for small residential systems up to 15 kW and 5000 kWh. This triggered an important market development which lasts till now. In 2015, 437 MW of PV systems were installed and 525 MW in 2016, pushing the PV installed capacity to close to 2,1 GW mark, mostly in the residential PV market.

A reverse auctioning system exists for large-scale PV systems, called SDE+ which attracted 48 MW in 2013, 137 MW in 2014 but only 3 MW in 2015 and 22 MW in 2016. more should come in the coming years with the SDE+ 2017 call expected to grant more than 2 GW to PV systems above 15 kW.

This environment is triggering the development of new business models. For example, contracts to purchase electricity from neighbours are developing, resulting in new community-based systems. The Dutch market is very competitive and it will be interesting to observe the fast evolution of net-metering and the potential reaction from grid operators, while high electricity prices are making grid parity accessible in the residential segment.

To reach the renewable energy goals in 2023, there is now a potential for 1 GW or more of PV installations a year.

With good research centers and companies active in the PV sector, the Netherlands appear as an interesting innovator that could accelerate the emergence of BIPV in Europe. From PV roads to concept for complete roof renewals, PV integrated in the built environment (and not only in buildings) could provide an interesting framework for the future in a country where free space is scarce and the built environment majoritary. From a market point of view, the political commitment to keep the net-metering scheme until the end of the decade offers a safe harbour for PV investment, before the expected transition to a pure self-consumption regulatory regime.

NORWAY

FINAL ELECTRICITY CONSUMPTION 2016	132	TWh
HABITANTS 2016	5	MILLION
IRRADIATION	800	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	11,4	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	26,6	MW
PV PENETRATION	0,0	%

The PV market in Norway was driven mainly by off-grid applications until 2014. However, this was taken over by grid-connected segmentation when it jumped ten-fold from 0,1 MW in 2013 to 1,4 MW at the end of 2014. 2015 saw a weak growth in commercial business installations, but this was offset with the growth coming from household systems. Therefore, the grid-connected segment increased modestly to 1,5 MW in 2015. In 2016 the grid-connected segment dominated the market completely with 10 MW installed: installations were split between commercial (7,4 MW) and residential (3 MW) installations.

Overall, the total installed capacity reached 27 MW at the end of 2016. The estimates for 2017 indicate further market growth despite weak incentives and low electricity-prices.

The off-grid market refers to both the leisure market (cabins, leisure boats) and the professional market (primarily lighthouses/lanterns along the coast and telecommunication systems). This segment is growing caused by an increasing number of larger hybrid systems with larger battery-capacities, diesel or petrol back-up generators and electrical conversion to 230 Volt AC.

Self-consumption for grid-connected systems is allowed under the 'Plus-customer scheme' provided that the customer is a net customer of grid-electricity on a yearly basis, and limits the maximum feed-in power to 100 kW. There are several drivers for the strong growth in the residential market segment during 2016. Environmental awareness and access to capital, especially among technological interested people who typically already drive electric cars, but also new business models where several companies now offer leasing of PV-systems.

From January 2016, owners of small PV systems below 15 kWp are eligible for a financial investment support provided by Enova SF, a public agency owned by the Ministry of Petroleum and Energy. Enova also offers financial supports for "Building with High-Energy Performance" where the energy performance goes beyond the normal technical norms. Environmental qualities is an increasingly important market parameter for stakeholders in the Norwegian building and construction sector. Enova has a strong focus on energy efficient buildings and supports innovative technologies and solutions. BIPV and associated batteries, and smart control is emerging along with new companies with innovative business models.

In 2014, the municipality of Oslo launched a capital subsidy for PV systems on residential buildings covering a maximum of 40% of the investment cost. The programme has been extended every year since the start and is funding installations also in 2017.

During 2015, self-consumption for large PV systems were under discussion to be eligible for el-certificate (Renewable Energy Certificates, RECS) market which created uncertainty for investors, but from 2016 PV-plants receive el-certificates for the total annual production for 15 years. The value of the el-certificates is not fixed, but are priced in the range of 0,15 NOK/kWh at the moment. Power-plants must be in operation within the end of 2020 to be part of the RECS support program.

With a low density of population, a nordic cold climate (which fits perfectly the use of PV) and an extremely high share (96-99%) of cheap (0,20-0,50 NOK/kWh in the summer), hydro-based renewable energy in the electricity mix, Norway is not expected to become a huge PV market. However, it represents an interesting showcase of PV possibilities, especially in combination with the increasing share of electric vehicles.

PORTUGAL

FINAL ELECTRICITY CONSUMPTION 2016	51	TWh
HABITANTS 2016	10	MILLION
IRRADIATION	1 600	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	52	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	517	MW
PV PENETRATION	1,6	%

The Portuguese PV market stood at 51,7 MW in 2016, registering a small increase with respect to the previous yearly level of installations. The market has been mostly driven by the FiT scheme. The industrial segment was the largest with 28 MW installed, while the other distributed segments reached 35,6 MW together. 16 MW of utility-scale plants were installed in Portugal in 2016. The total installed capacity reached about 516 MW end of 2016.

By October 2014, the new self-consumption and FIT regime regulation for small units (systems under 250 kW) was published.

On January 2016, the Green Tax Reform was implemented setting the maximum tax depreciation of solar at 8%. The proposal of reducing 50% of the Municipal Real Estate Tax (IMI) for RES power producing buildings was accepted.

In 2013, given the difficult financial situation of the country, the government decided to revise targets under the National Renewable Energy Action Plan for 2020 and the official goal for PV was reduced from 1,5 GW to 720 MW in 2020.

SPAIN

FINAL ELECTRICITY CONSUMPTION 2016	265	TWh
HABITANTS 2016	46	MILLION
IRRADIATION	1 300	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	58	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	5 483	MW
PV PENETRATION	3,0	%

In 2007 and 2008, Spain's FiT programme triggered a rapid expansion of the PV market. After a moratorium in October 2008 that made the market go down, in January 2012 a new moratorium was put in place for all the renewables projects with FiT. In 2016, only 55 MWdc were installed in Spain and the total installed capacity tops almost 4,7 GWac (5,5 GWdc), which can be explained by the difficult economic environment and the constraining PV policies.

In the summer of 2013, the Government announced a new reform of the electricity market. Under the 24/213 Power Sector Act, the FiT system was stopped in July 2013 and the new schemes are based on the remuneration of capacity rather than production. The new system is based on government-estimated standard costs, with a legal possibility to change the revenues allocated every three years. Projects are financed at market price and their incomes are complemented with revenues should they achieve the level of profitability established by the government. This has caused many projects to be in a state of default. The largest projects have changed hands, since international investors found interest in the acquisition of this projects.

The 24/2013 Power Sector Act considers very restrictive forms of self-consumption. The regulatory framework for self-consumption was developed under Royal Decree (RD) 900/2015 and didn´t change in 2016. This RD established that the maximum capacity of the self-consumption installation must be equal or below the contracted capacity. It also specifies two types of self-consumers:

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- Type 1: maximum capacity installed of 100 kW – there is no compensation for the electricity surplus fed in the grid.
- Type 2: not limit to the allowed capacity – the surplus can be sold in the wholesale market directly or through an intermediary. A specific grid tax of 0.5 EUR/MWh has to be paid together with a 7% tax on the electricity produced.

Regulation indicates that self-generated power above 10 kW is charged with a fee per kWh consumed as a "grid backup toll", commonly known as the "sun tax". Adding battery storage to the installation also implies an additional tax. In 2016 geographical compensation is not allowed, and self-consumption for several end customers or a community is not allowed either.

Grid parity has been reached in Spain thanks to two factors: high solar irradiation resource and better prices for components. PV installations have decreased their price 80% in the past five years. Given the context of a lack of feed-in-tariff, the future of the Spanish PV market lies in the deployment of large PV plants thanks to the renewable energy tenders planned to meet the EU energy and climate targets and the Paris Agreement. In 2016, however, the first Spanish renewable energy tender only allowed wind and biomass to participate. PV projects were therefore left out. The tender was not successful because of its design, which allowed projects to participate at zero cost. For 2017 new tenders have been announced, which should in theory favor PV and lead to several GW of installations before 2020. PV project developers are also looking into other sources of financing, such as PPAs or merchant.

One of the key objectives supported by an important part of the civil society and policymakers is the elimination of some self-consumption barriers, like technical and administrative barriers. This would power the development of self-consumption in Spain.

SWEDEN

FINAL ELECTRICITY CONSUMPTION 2016	140	TWh
HABITANTS 2016	10	MILLION
IRRADIATION	950	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	79	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	205	MW
PV PENETRATION	0,1	%

PV installations increased once again in Sweden in 2016: 79 MW were installed compared to 47 MW one year before. In the last ten years, more grid-connected capacity than off-grid capacity has been installed and grid-connected PV largely outscores off-grid systems, a trend which is now visible in Finland and Norway as well. The grid-connected market is almost exclusively made up of roof mounted systems installed by private persons or companies: residential installations reached 21 MW and commercial or industrial ones 48 MW. BIPV represented less than 2 MW and ground-mounted systems less than 7 MW.

The total installed capacity reached the 200 MW mark in 2016 as the total installed capacity was 204,45 MW, compared to 126,8 MW at the end of 2015.

The off-grid market stabilized to around 1,5 MW. As in 2015, and in the same way as in many European countries, the large increase of installed systems occurred within the submarket of grid-connected systems. With 77,6 MW installed in 2016 for grid-connected PV, the cumulative grid-connected PV reached 193 MW while the off-grid capacity established itself at 12,7 MW at the end of 2016. The strong growth in the Swedish PV market is due to lower system prices, a growing interest in PV and a direct capital subsidy along with newly introduced tax deduction system.

Incentives

A direct capital subsidy for installation of grid-connected PV systems that have been active in Sweden since 2009. It was first prolonged for 2012 and later extended until 2015. These funds were completely used in 2014 already, which pushed the government to add 50 MSEK for 2015. Due to the much higher interest in the support scheme, as compared to the allocated budget, the waiting time for a decision about the investment subsidy is quite long, in general about 1-2 years. In an effort to lower the waiting times the government decided in the autumn of 2016 to greatly increase the annual budget of this scheme for the years 2016–2019 with 235, 390, 390 and 390 MSEK, respectively.

Net-metering has been discussed and investigated several times but it has not been introduced. In the meantime, some utilities have decided to put in place different compensation schemes for the excess electricity of micro-producers. In addition, from 2015 the government introduced a tax deduction of 0,06 EUR per kWh for the excess electricity fed into the grid, which PV owners with a fuse below 100 ampere is entitled to. This remuneration is in addition to the compensation offered by the utility company. The tax deduction will apply on the income tax, and has a cap of 3 100 EUR per year.

Additionally, a tradable green certificates scheme exists since 2003, but only around 48,6 MW of the 115,7 MW of grid-connected PV installations in Sweden are using it so far due to the complexity for micro-producer to benefit from the scheme. It is expected that the Swedish green electricity certificate system will be prolonged to 2030.

The Swedish PV market is in the short term expected to continue to grow with the introduction of the tax deduction for micro-producer, the increase of supports from utilities, regulation changes that lessen the administrative procedure and the increased budget for the investment subsidy. However, the administrative burden and long queue in getting the investment subsidy need to be addressed properly in order for market to thrive in the upcoming years.

SWITZERLAND

FINAL ELECTRICITY CONSUMPTION 2016	58	TWh
HABITANTS 2016	8	MILLION
IRRADIATION	950	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	270	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	1 664	MW
PV PENETRATION	2,3	%

270 MW were connected to the grid in Switzerland in 2016, a 20% decrease compared to 2015, but a rather stable market looking at the last five years. In total, Switzerland hosted 1,66 GW of PV systems at the end of 2016.

Almost the entire PV market consists of rooftop applications and the few ground mounted PV applications are relatively small in size. The total off-grid applications market stood at level of less than 4 MW with a market below the 1 MW mark. Residential installations represented 50 MW, the commercial segment about 160 MW and the industrial one 40 MW. BIPV represented around 20 MW thanks to a special premium offered by the Swiss FiT and direct subsidy scheme. Out of these 20 MW, 15 MW are in the residential segment. Ground-mounted applications represented less than 1 MW in 2016.

The limitations of a new funding scheme with Feed in tariffs and direct subsidies had a negative effect on the market and pushed it down. Since only small installations below 30 kW have still a guaranteed right for direct subsidies, the market for larger systems is drying out.

Switzerland has the national capped FiT scheme financed through a levy on electricity prices but the main drivers for market development in 2016 were self-consumption and the direct subsidy scheme for small installations up to 30 kW introduced in 2014. Self-consumption is now the main driver for residential as well as commercial sized systems. Depending on grid cost conditions as well as energy buy-back tariffs, some DSO allow the operation of PV systems to be profitable for the time being.

Besides the (capped) national FiT scheme there are still many regional, local and utility-supported incentives schemes. These are either based on direct subsidies or FiTs equal or below the federal level.

The average size of the systems installed in 2016 was about 30 kW. About 9 300 systems have been installed. More than 6 800 systems are smaller than 20 kW (and can be considered as residential systems).

In 2016 PV contributed to 2,3 % of the total electricity consumption and will be able to cover at least 2,8 % in 2017. With this production level, PV has become second to hydropower in the renewable electricity portfolio.

Since the referendum in May 2017 where the Swiss voted for new support schemes for renewables and put a ban on new nuclear power plants, the market outlook for Switzerland looks quite good.

OTHER COUNTRIES

2,15 GW of PV systems (against 4,1 GW in 2015) have been installed in 2016 in the United Kingdom (UK), bringing the total installed capacity to more than 11 GW. The UK was again the first European market in 2016, ahead of Germany, due to a strong deployment of utility-scale PV. This market is driven by two main support schemes: a generation tariff coupled with a feed-in premium and a system of green certificates linked to a quota (called ROC, for Renewable Obligation Certificates). The generation tariff is granted for small size PV systems. Systems below 30 kW receive in addition to the generation tariff, a bonus for the electricity injected into the grid (the "export-tariff", a feed-in premium above the generation tariff), while the self-consumed part of electricity allows for reducing the electricity bill. This scheme can be seen as an indirect support to self-consumption; the export tariff being significantly smaller than retail electricity prices. Above 30 kW, excess electricity is sold on the electricity market.

For larger systems, the UK has implemented its own RPS system, called ROC. In this scheme, PV producers receive certificates with a multiplying factor. This scheme applies to buildings and utility-scale PV systems. This system has now been replaced for systems above 5 MW by a market premium using a Contract for Differences (CfD) to guarantee a fixed remuneration based on a variable wholesale electricity price. The UK market is expected to continue decreasing in 2017 and even more in a near future due to the changes in incentives.

Bulgaria experienced a very fast PV market boom in 2012 that was fuelled by relatively high FiTs. Officially 1 GW of PV systems were installed in this country with 7 million inhabitants in a bit more than one year, creating the fear of potential grid issues. In addition to possible retroactive measures aiming at reducing the level of already granted FiTs, Bulgarian grid operators have opted for additional grid fees in order to limit market development. The consequence is that the market went down to around 10 MW in 2016.

In the Czech Republic, driven by low administrative barriers and a profitable FiT scheme, the Czech PV market boomed in 2009 and especially in 2010. With more than 2 GW installed, installations stopped and the total installed capacity was even revised downwards. Composed mainly of large utility-scale installations, the Czech PV landscape left little space to residential rooftop installations. At the end of 2015, the energy regulators used the false excuse (that European institutions should validate the FiT payments) to discontinue paying the FiT to existing plants, one more attempt, after the tax on FiT, to reduce the cost of previous FiT expenses. And to reduce the confidence of investors into PV in Czech Republic. in 2016, about 5 MW were installed in the country. The market could start to move again in 2017 under new policies.

After having installed 912 MW in 2012, Greece installed 1,04 GW of PV systems in 2013, and reached 2,6 GW of installed capacity. The market continued the downward trend with almost nothing installed in 2016. The market was driven by FiTs that were adjusted downwards several times. The installations are mainly concentrated in the rooftop segments (commercial and industrial segments in particular). With dozens of islands powered by diesel generators, the deployment of PV in the Greek islands went quite fast in 2012 and 2013. Due to the rapid market uptake, grid operators asked in 2012 to slow down the deployment of PV, in order to maintain the ability of the grid to operate within normal conditions.

EUROPE / CONTINUED

Romania experienced a rapid market development with 1,1 GW installed in one year, driven by an RPS system with quotas paid during 15 years. Financial incentives can be granted but reduce the amount of green certificates paid. In 2014, the government decided to freeze 2 out of 6 green certificates until 2017 in order to limit the decline of the green certificates price on the market. In addition, the number of green certificates granted for new PV installations went down to 3. The total installed capacity reached 1382 MW with 70 MW installed in 2016. Romania illustrates the case of an RPS system with Green Certificates where the level of the RPS was not adjusted fast enough to cope with the growth of installations.

After years outside of the global PV market, Poland installed around 100 MW in 2016 and the total installed capacity reached 199 MW at the end of the year. A large part of installations took part in the residential and commercial segments. The Polish government is currently supporting solar through net metering (up to 40 kW) and an auction mechanism for large-scale projects (over 40 kW). The two schemes, which replaced the green certificate mechanism, were introduced with a new renewable energy law in July 2016. Under the net metering scheme, operators of PV systems up to 10 kW are refunded 80% for each kilowatt they inject into the electricity system, while owners of PV installations ranging in size between 10 kW and 40 KW are refunded 70%. As for the auction mechanism, the government held the first auction in late December 2016. Through the tender, a total of 82 renewable energy projects up to 1 MW were selected, the majority for MW-sized PV plants. The lowest bid was about 6,2 USDcents/kWh.

Hungary also experienced some market development in 2016, with around 100 MW installed and around 270 MW of total installed capacity at the end of the year. Most of this capacity comes in the form of PV systems up to 50 kW installed under the country's net-metering scheme up to 50kW. The remaining cumulative capacity is represented by PV systems installed under the FIT scheme. Under this program, PV projects with simplified license and capacity between 50 kW and 500 kW can be financed while PV projects over 500 kW require the full licensing process. Installations in 2015 and 2016 reached 100 MW, while in 2014 and 2013 new installations reached 36.9 MW and 18,8 MW, respectively.

Other European countries have experienced some market development in 2016, driven by a mix of FiTs, self-consumption measures and calls for tenders that are now in place. Slovakia experienced very fast market development in 2011 with 321 MW installed but less than 1 MW with reduced incentives and a rather negative climate towards PV investments in 2014. Ukraine has seen a spectacular market development from 2011 to 2013 with 616 MW of large installations. However, the political instability will have long term impacts on the PV development in the country.

In total, the European markets represented 6,6 GW of new PV installations and 105,84 GW of total installed capacity in 2016.

MIDDLE EAST AND AFRICA

Continuing the rising development trend started in 2014 and 2015, many countries had considered PV as one of the main renewable source in producing electricity in 2016. Several countries are defining PV development plans and the prospects on the short to medium term are positive. The Middle East is now the most competitive place for PV installations, with PPAs granted through tendering processes among the lowest in the world.

ISRAEL

FINAL ELECTRICITY CONSUMPTION 2016	56	TWh
HABITANTS 2016	9	MILLION
IRRADIATION	1 450	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	130	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	1 016	MW
PV PENETRATION	2,6	%

Israel installed 130 MW of new PV systems in 2016, whereas the country installed several years more than 200 MW. In total, close to 1 GW of PV systems were operational in Israel at the end of 2016. Of this capacity, around 200 MW comes from PV projects exceeding 12 MW, while the remaining power is represented by residential installations up to 15 kW (50 MW), commercial installations ranging in size from 15 kW to 50 kW (240 MW), and distributed generation PV plants up to 14 MW (downsized to 12 MW) (315 MW). On top of this, there are more than 100 MW of capacity installed under the country's net metering scheme.

2016 has seen a dramatic decline in the electricity cost in Israel (around 15%) leading to tougher competition of renewable energy. However, it is still clear that PV system are close to grid parity.

A tariff has been set up for RE manufacturers and it is not subjected to FIT quotas. The tariff is the recognized conventional electricity generation tariff + a premium for emissions reduction (currently 0,26 + 0,08 ILS). The main issue for PV entrepreneurs now, is the fact that the rate fluctuates with conventional electricity generation rates, and is thus not guaranteed. An example for this uncertainty was seen last year with the steep decline of electricity generation costs.

In December 2014 a first utility-scale system was connected to the transmission grid (37,5 MW). Most of the new installations continued to be medium size: between 500 kW to several MW with connection to the distribution grid. In the next two years, additional PV power is expected to come mostly from large plants installation. The capacity factor for PV in Israel is considerably higher than in Europe and stands around 19% for actual production on an annual average. The penetration of single axis tracking systems is increasing due to the higher capacity factor, standing at around 24%.

Due to the scarcity of land, efforts are being made to develop PV systems as a secondary land usage. In addition to the obvious rooftop solution, the option of using water reservoirs, and waste land is being tested also the use on the same plot of land with some types of agriculture. Tracking systems are particularly fit for this, as the spacing between the panels is larger.

Government support is given in the form of guaranteed FiT for 20 years. FiTs vary by project nature, size and other parameters. FiT have decreased considerably over the last few years, and are expected to continue their decline. Israel is trying a new bidding system for the FIT in large PV project based on quota and price. Current starting price for this system is 0,27 ILS per kWh (0,07 USDcents).

Because FiT includes a subsidy, which is paid by the electricity consumer, there are quotas (Caps) for each renewable energy category. In 2014 an additional quota of 340 MW for PV was issued, to be evenly spread during 2016-2017. This quota comes mostly at the expense of Biomass electricity production, for which it was decided that the original targets were too high, due to lack of source material. In addition, there is a quota of 180 MW, which is expected to be converted from CSP to PV. The series of 1 GW tenders launched by the Israeli government at the beginning of 2017 is intended to help the country reach a target of 10% share of renewables in its energy mix by 2020. Solar is expected to grow by another 2.5 GW by then. Overall, Israel is targeting to cover its energy consumption with renewables by 13% in 2025, and by 17% in 2030.

Net-Metering/Self-Consumption.

In 2013, a net-metering scheme was implemented for all RES with a cap of 200 MW. This programme was extended to 2016.

- Real-time self-consumption simply reduces the electricity bill.
- Excess PV production can be fed into the grid in exchange for monetary credits, which can be used to offset electricity consumption from the grid during the following 24 months. The credit is time of day dependent. Thus a small overproduction at peak times, can offset a large consumption at low times.
- Credits can be transferred to any other consumer and in particular to other locations of the same entity.
- One has the option to sell a preset amount of the electricity to the grid for money (and not credit), but at a conventional manufacturing price (currently 0,30 NIS/kWh).
- All the electricity fed into the grid is subject to Grid and Services charges.
- A back-up fee that aims to cover the need to back-up PV systems with conventional power plants will be imposed, when the installed capacity will reach 1,8 GW. This fee is technology dependent and will grow for solar from 0,03 NIS/kWh to 0,06 NIS/kWh after 2,4 GW will be installed.
- A balancing fee (0,015 NIS/kWh) for variable renewable sources has also been introduced.
- Finally, a grid fee that depends on the time of day and day of the week and connection type (to transmission, distribution, or supply grid) has been introduced and ranges between 0,01 NIS/kWh and 0,05 NIS/kWh.

TURKEY

FINAL ELECTRICITY CONSUMPTION 2016	222	TWh
HABITANTS 2016	80	MILLION
IRRADIATION	1 527	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	583	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	849	MW
PV PENETRATION	0,6	%

Once a very small PV market, Turkey aims now to reach 5 GW of PV installations by the end of 2023 according to its Strategy Plan (2016 - 2019) and to increase its electricity production capacity from solar power to 10 GW until 2030. Following the upward development trend from the previous year, the Turkish PV market surged to 583 MW in 2016.

Turkey considers two different procedures to install PV: licenced projects without size limit and unlicensed projects, which are limited to 1 MW. To date, only 2 licensed PV plants have been installed in Turkey with a total installed capacity of 12,9 MW. Given the complexity of the process in the past, some investors preferred to set up MW-scale PV plants unlicensed. Such limits apply for projects that inject electricity into the grid but projects self-consuming all of their PV production are not limited in size.

The market increased mainly thanks to "unlicenced" projects. More than 4 GW of projects have already received the approval and 1,5 GW installed by June 2017. Cumulative grid-connected installed PV power in Turkey reached 848,7 MW at the end of 2016. As the speed of installations accelerates, the medium scenario for PV development in 2017 sees the market in Turkey going much higher than in 2016. 1 to 1,5 GW of newly installed capacities are expected in 2017.

The remuneration of PV projects is based on a traditional FiT system paid 13,3 USDcents/kWh during 10 years, with different levels according to the share of local production: PV modules, cells, inverters, installation and construction can benefit from an additional FiT which may reach up to 6,7 USDcents/kWh.

As of 19 December 2016, PV module imports will be charged an import tax, based on weight – specifically 35 USD/kg. An exemption from the tax exists by presenting an "Investment Incentive Certificate" for the approved projects which already received this certificate before December 2016.

Solar Energy is the most important alternative energy resource which is still untapped in Turkey with a potential of dozens of GW. Given the current support from the government, a rapidly growing market in Turkey, in the near future, will not be surprising.

MIDDLE EAST AND AFRICA / CONTINUED

SOUTH AFRICA

FINAL ELECTRICITY CONSUMPTION 2016	238	TWh
HABITANTS 2016	56	MILLION
IRRADIATION	1 702	kWh/kW
2016 PV ANNUAL INSTALLED CAPACITY	70	MW
2016 PV CUMULATIVE INSTALLED CAPACITY	1 030	MW
PV PENETRATION	1,1	%

South Africa became the first African PV market in 2014 with around 960 MW installed, mostly ground mounted, but the momentum didn't last and at the end of 2016, the total installed capacity reached 1 030 MW. The large majority of this capacity has been in large scale ground mounted systems, while the rooftop solar photovoltaic (RTPV) market, despite its enormous potential, remains dormant. Small distributed generators like RTPV have the potential to grow rapidly (around 500 to 1000 MW annually), as only small financial investments per project are required and project planning can hypothetically be performed quite quickly.

The indicative installed capacity of small scale embedded generation (SSEG) in South African municipalities is in the order of 17 MWp.

The Renewable Energy Independent Power Producer Procurement Programme

A variety of mid- and long-term interventions has been implemented by the government of South Africa in order to quickly acquire new capacities while ensuring sustainable development. The South African Department of Energy through the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), a subsidy mechanism for large scale and grid-connected renewable energy systems such as PV to promote an increase of installed capacities by independent power producers (IPPs). A total of 8.1 GW of renewables (mainly from wind and PV) for procurement from IPPs has already been allocated. Out of this, 6.3 GW have reached preferred bidder status, 4.0 GW have financially closed and signed the Power Purchase Agreements with Eskom and 1 474 MW of solar PV were operational and fed energy into the grid by Dec 2016.

Rooftop Solar PV – Wiring code

The lack of a clearly defined wiring code for small Rooftop PV (RTPV) systems is one of the key remaining barriers to preventing the market from a rapid and cost-effective expansion. A working group has been established to put together a standard for South Africa on connecting embedded generation up to 1 MW. It will support the safe operation of embedded generation for consumers, installers and grid operators.

PV Green Card

The drastic cost reduction of solar PV systems together with rising electricity tariffs and uncertainty of supply, have made solar PV increasingly attractive both for residential and commercial users in South Africa. However, there is no industry-wide, standardized PV licencing system or registration process. For this reason, the South African Photovoltaic Industry Association (SAPVIA) together with the industry developed PV Green Card to promote quality and safe solar PV installations. The main motivation for the programme is the peace of mind that your solar PV installation complies with industry and international best practice. The idea is to create a safe environment for end clients, installers and investors. The procedure is simple: SAPVIA gives out guidelines for assessments where installers undergo a theoretical and practical test which they must pass in order to be included in the list of certified installers in the PV Green Card database. Then for every installation, a PV Green Card is issued by the certified installers in order to proof the correctness of the installation. The plan is to make the PV Green Card a seal of quality and mandatory for any official installations.

Local Content

South Africa took a decision focussed on re-industrialisation in the country in order to drive local manufacturing and sustainable job creation. This decision is embedded in the Public Procurement Policy Framework Act (PPPFA) Regulations, which mandate the Department of Trade and Industry (DTI) to designate strategic sectors of the economy for local procurement. The Department of Trade and Industry designated a number of products for local content in various sectors of the economy. In the latest instruction note issued by the National Treasury, the DTI designated the Solar PV system component at various levels of local content as follows: Laminated PV Module (15%), Module frame (65%), DC Combiner Boxes (65%), Mounting Structure (90%) and Inverter (40%). All state entities procuring Solar PV plants are required to comply with the local content requirements.

OTHER COUNTRIES

In MEA (Middle East and Africa) countries, the development of PV remains modest but almost all countries saw a small development of PV in the last years and few of them a significant increase. There is a clear trend in most countries to include PV in energy planning, to set national targets and to prepare the regulatory framework to accommodate PV.

Winning bids in tenders in the United Arab Emirates (Dubaï and Abu Dhabi) and Jordan have reached extremely low levels down to below 0,03 USD/kWh. Dubai will install 1 000 MW in the coming years and more have been announced. Jordan at one time announced 200 MW, then that it aimed for at least 1 GW of PV in 2030. Qatar launched its first tender for 200 MW in October 2013. Saudi Arabia launched a tender in 2017 which will provide most probably the lowest bid ever seen in PV.

Other countries in the Middle East have set up plans for PV development at short or long term. Lebanon has set up a FiT and Saudi Arabia has made plans for PV development which have been delayed but the country is expected to launch its first tender in 2016.

In Africa, besides South-Africa, the fastest mover was Egypt, which has announced plans to develop PV. A FiT program targets

2,3 GW of installations (2 GW between 50 kW and 50 MW) and 300 MW below 50 kW. In addition, 5 GW of projects have been signed in 2016 for installation before 2020. But the market itself remained constrained.

In Morocco, PV could play an important role next to CSP and certainly in the distributed segments. In Algeria, a new FiT scheme has been set up in 2014 for ground-mounted systems above 1 MW. In addition, 400 MW have been planned and a 4 GW tender was in preparation in 2017.

In several African countries, the interest for PV is growing, while the market has not really taken off yet. At least large-scale plants are planned in several countries to replace or complement existing diesel generators, from 1,5 to 155 MW in size; these plants are planned or being developed in Rwanda, Ghana, Mali, Ivory Coast, Burkina Faso, Cameroon, Gambia, Mauritania, Benin, Sierra Leone, Lesotho and more. Since PV offers access to cheap electricity, it is highly expected that it will develop in most places, under market conditions which have little in common with developed markets.

TABLE 2: 2016 PV MARKET STATISTICS IN DETAIL

COUNTRY	2016 ANNUAL CAPACITY (MW)				2016 CUMULATIVE CAPACITY (MW)			
	GRID-CONNECTED		OFF-GRID	TOTAL	GRID-CONNECTED		OFF-GRID	TOTAL
	DECENTRALIZED	CENTRALIZED			DECENTRALIZED	CENTRALIZED		
AUSTRALIA	780	60	36	876	5 360	416	209	5 985
AUSTRIA	162	7	1	171	1 094	7	7	1 108
BELGIUM	173	0	0	173	2 767	656	0	3 423
CANADA	54	89	0	143	790	1 872	61	2 723
CHILE	0	495	0	495	0	1 071	0	1 071
CHINA	4 230	30 310	10	34 550	10 290	67 430	360	78 080
DENMARK	20	51	0	71	666	190	3	858
FINLAND	16	1	0	17	26	1	10	37
FRANCE	316	243	0	559	4 573	2 561	30	7164
GERMANY	1 225	251	0	1 476	30 439	10 697	50	41 186
ISRAEL	61	69	0	130	529	483	4	1 016
ITALY	362	20	0	382	7 810	11 473	14	19 297
JAPAN	4 620	3 236	34	7 890	29 244	12 635	161	42 041
KOREA	100	804	0	904	535	3 862	0	4 397
MALAYSIA	64	8	0	72	328	8	0	336
MEXICO	72	72	0	143	177	187	25	389
NETHERLANDS	525	0	0	525	2 042	43	0	2 085
NORWAY	10	0	1	11	14	0	13	27
PORTUGAL	36	16	0	52	202	307	8	517
SOUTH AFRICA	0	70	0	70	0	1 030	0	1 030
SPAIN	35	2	20	58	3 136	2 204	143	5 483
SWEDEN	71	7	2	79	181	12	13	205
SWITZERLAND	270	0	0	270	1 657	3	4	1 664
THAILAND	0	1 027	0	1 027	0	2 412	34	2 446
TURKEY	0	583	0	583	12	837	0	849
USA	4 169	10 593	0	14 762	16 017	24 419	0	40 436
TOTAL IEA PVPS COUNTRIES	17 372	48 013	105	65 489	117 888	144 815	1 150	263 853
NON IEA PVPS COUNTRIES				9 787				35 833
REST OF THE WORLD ESTIMATES				450				3 709
TOTAL				75 727				303 395

SOURCE IEA PVPS & OTHERS.

three

POLICY FRAMEWORK

PV development has been powered by the deployment of support policies, aiming at reducing the gap between PV's cost of electricity and the price of conventional electricity sources over the last ten years. These support schemes took various forms depending on the local specificities and evolved to cope with unexpected market evolution or policy changes.

In 2016, the price of PV systems, as we have seen, and accordingly the cost of producing electricity from PV (LCOE) continued to drop to levels that are in some countries close or even below the retail price of electricity (the so-called "grid parity") or in some cases close to or below the wholesale price of electricity.

In several countries, the so-called "fuel parity" has been reached. This means that producing electricity with a PV system is now in most cases cheaper than producing it with a diesel generator, which will have a tremendous impact on the future of PV as an electricity source for rural electrification.

But PV systems are not yet fully competitive in all markets and segments and the development of PV still requires adequate support schemes as well as ad hoc policies with regard to electricity grids connections, building use and many others. This chapter focuses on existing policies and how they have contributed to develop PV. It pinpoints, as well, local improvements and examines how the PV market reacted to these changes.

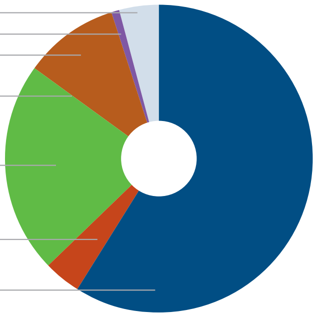
PV MARKET DRIVERS

Figure 13 shows that about only 1% of the world PV market was driven by pure self-consumption or the sole competitiveness of PV installations in 2016. It also means 99% of the global PV market depends either on support schemes or adequate regulatory frameworks. This number has slightly increased compared to the 96% seen in 2014 due to a finer understanding of some regulations but as a whole the global PV market remains incentives or regulatory driven. The share of off-grid installations can also be considered as part of the competitiveness-driven market.

In 2016 a large part of the market still remained dominated by FiT schemes (59%, down from 63%) granted without a tendering process. If we add 4% of PV installations granted through a tendering process, the share of PV installations receiving a predefined tariff for part or all of their production remained stable. Subsidies aiming at reducing the upfront investment (or tax breaks), used as the main driver for PV development represented around 22% of the installations, up compared to 2015 due to the US market growth. Incentivised self-consumption including net-billing and net-metering was the main incentive in 2016 for 10% of the world market. Various forms of incentivized self-consumption schemes exist (and are often called improperly net-metering), such as Italy with the Scambio Sul Posto, Israel, or Germany. Green certificates and similar schemes based on RPS represented only a minority of the market with 4%.

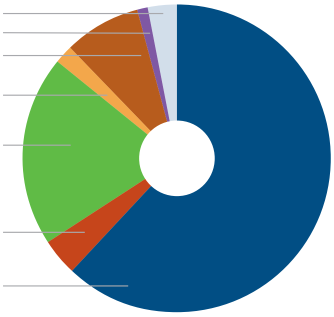
Historically, the dominance of FiTs and direct subsidies is similar but even more visible in Figure 14.

FIGURE 13: 2016 MARKET INCENTIVES AND ENABLERS



SOURCE IEA PVPS & OTHERS.

FIGURE 14: HISTORICAL MARKET INCENTIVES AND ENABLERS



SOURCE IEA PVPS & OTHERS.

The emergence of calls for tenders has been confirmed again in 2016, with new countries using this legal tool to attribute remunerations to PV projects under certain conditions. Jordan, Peru, Mexico, UAE (Abu Dhabi) and many others have joined the list of countries using calls for tenders to grant PPAs for PV plants. The result of these calls for tenders is a guaranteed payment for PV electricity, or in other words, a FiT. Such tenders represented around 4% of the world market in 2016 and are growing. Such tenders can take various forms, and integrate often additional obligations for the bidder, which are sometimes used to protect the local market or favor innovative technologies. This number is expected to develop fast in the coming years, under the pressure of markets which granted in 2016 and 2017 important volumes, such as India, Spain, Mexico and much more.

Incentives can be granted by a wide variety of authorities or sometimes by utilities themselves. They can be unique or add up to each other. Their lifetime is generally quite short, with frequent policy changes, at least to adapt the financial parameters. Next to central governments, regional states or provinces can propose either the main incentive or some additional ones. Municipalities are more and more involved in renewable energy development and can offer additional advantages.

In some cases, utilities are proposing specific deployment schemes to their own customers, generally in the absence of national or local incentives, but sometimes to complement them.

COST OF SUPPORT SCHEMES

The cost of the FiT or similar incentives can be supported through taxpayers money or, and this is the most common case, at least in Europe, through a specific levy on the electricity bill (Austria, Germany, France, Italy, etc.). This levy is then paid by all electricity consumers in the same way, even if some countries, Germany for instance, have exempted some large industrial electricity consumers for competitiveness reasons. In Germany, in order to maintain the financing of systems, prosumers with systems above 10 kW are now required to pay 40% of this levy on the electricity consumption coming from PV.

The amount of cash available per year can be limited and in that case, a first-come first-serve principle is applied (Austria, Switzerland). Most countries did not impose a yearly cap on FiT expenditures in the past, which led to fast market development in Japan, China, Germany, Italy, Spain and many others.

Some examples:

Belgium: green certificates have to be bought by utilities if they don't produce the required quotas of renewable electricity, which make these costs transparent. However, when PV producers are not able to sell these certificates, they are bought by the Transmission System Operator which re-invoices this to customers through their electricity bill.

Denmark: the PSO (Public Service Obligation) covers RE remuneration costs in addition to other related subjects. It amounted to 0,25 DKK/kWh and the total cost amounted to 8,4 BDKK in 2015. It is paid by electricity consumers. By mid 2016 the government has proposed to give up the PSO scheme and use the state budget instead, but this proposal is still in the political process.

France: The CSPE surcharge part for PV amounted to 2,2 BEUR in 2016, or around 22.5 EUR/MWh. Furthermore, in support of the Energy transition, the Energy transition financing fund (Fonds de financement de la Transition énergétique) has been raised to 1,5 BEUR.

Germany: The EEG surcharge that covers the cost of all renewable sources is paid by all electricity consumers, with an exemption for large industrial consumers. Since 2014, some prosumers are paying a part of the surcharge on the self-consumed PV part. In 2016, EEG surcharge was 6,35 EURcts/kWh, which is twice more than initial value of EEG surcharge in 2014 - 2,54 EURcts/kWh. 2,7 EURcts/kWh of this surcharge covers PV installations. End users must pay the value added tax (19%) on this surcharge so that the costs imposed on private households increases to 7,56 EURcts/kWh for all renewable energies.The contribution of PV is considered as smal compared to wind in the last year.

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Italy: around 3,95 EURcts/kWh are paid by the electricity consumers in the residential sector at the end of 2016 (including around 2 EURcts/kWh for PV) and smaller amount by others final electricity users. The total annual cost amounts to 15,9 BEUR for all RES including 6,7 BEUR for PV.

Japan: Surcharge to promote renewable energy power generation for an household was set at 2,25 JPY/kWh in April 2017 and 2,64 JPY/kWh from May 2017 to April 2018. High-volume electricity users such as manufacturers are entitled to reduce the surcharge. The amount of purchased electricity generated by PV systems under the FIT program is around 93,7 TWh as of the end of December 2016, exceeding 3,8 TJPY in total.

Malaysia: consumers above 300 kWh/month are paying a surcharge for the RE Fund that finances the FiT. It represented around 1,6% of the electricity price paid by retail consumers.

Spain: the surcharge for all renewables accounted for 2,3% of the total electricity bill for industrial consumers and 6,5% for household consumers. In 2015, the total amount collected to support PV was 2 432 MEUR. In 2016, the remuneration for renewable energy sources, CHP and waste was 2.3% of the total electricity bill for industrial consumers and 6.5% for household consumers according to European statistics.

USA: the ITC tax break is borne by the federal budget indirectly (since the budget is not used but it represents rather a decrease of the potential income from PV development costs). Beside federal benefits, solar project developers can rely on other state and local incentives, which come in many forms, including — but not limited to — up-front rebates, performance-based incentives, state tax credits, renewable energy certificate (REC) payments, property tax exemptions, and low-interest loans. Incentives at both the federal and state levels vary by sector and by whether or not the systems are utility scale or distributed

FEED-IN TARIFFS

The concept of FiTs is quite simple. Electricity produced by the PV system and injected into the grid is paid at a predefined price and guaranteed during a fixed period. In theory, the price could be indexed on the inflation rate but this is rarely the case. This assumes that a PV system produces electricity for exporting into the grid rather than for local consumption. The most successful examples of FiT systems can be found in China, Japan, Germany and Italy (until 2013), to mention a few. The attractiveness of FiT has been slightly reduced but they still drive a large part of the PV market. While FiTs still represent more than 59% of the 2016 PV market, they have lost ground in European countries where they are mostly constrained.

National or Local

Depending on the country specifics, FiT can be defined at national level (China, Japan, Germany, etc.), at a regional level (Australia, Canada) with some regions opting for and others not, or with different characteristics. In 2011, the French FiT law introduced a geographical parameter in the FiT level, in order to compensate for the difference of solar resource in its regions: up to 20% more was paid for northern installations.

FiT can also be granted by utilities themselves (Austria, Sweden and Switzerland), outside of the policy framework as a way to increase customers' fidelity.

Automatic or Ad Hoc Adjustment

When the budget available for the FiT payments is not limited, market regulation must come from another control measure. It is assumed that most market booms in countries with unlimited FiT schemes were caused by an imbalance between the level of the tariffs and the declining cost of PV systems. With the rapid price decrease of PV systems over the last years, the profitability of PV investments grew very quickly when the level of the FiT was not adapted fast enough. This situation caused the market boom in Spain in 2008, in Czech Republic in 2010, in Italy in 2011 and to a certain extent in China in 2015, 2016 (and 2017). And in many other countries.

The "corridor" principle has been experimented in Germany since 2011 and was effective in 2013. The level of the FiT can be adapted on a monthly basis in order to reduce the profitability of PV investments if during a reference period (one year), the market has grown faster than the target decided by the government. The first attempt was hardly successful in Germany, with long delays between the FiT updates that allowed PV investment to remain highly profitable during several months, leading for instance to the tremendous December 2011 market boom where 3 GW were installed in Germany. In 2016, due to a low market level and unachieved targets, the FiT was not decreased in Germany.

In the last years, other countries adopted the principle of decreasing FiT levels over time, with sometimes (France and Italy) a clear pattern for the future. However few countries have opted for a clear decrease strategy and adapt their FiT on a regular basis, such as Japan or China.

FiT remains a very simple instrument to develop PV, but it needs to be fine-tuned on a regular basis in order to avoid uncontrolled market development.

Tendering

Calls for tender are another way to grant FiT schemes with an indirect financial cap. This system has been adopted in many countries around the world, with the clear aim of reducing the cost of PV electricity. Since bidders have to compete one with each other, they tend to reduce the bidding price at the minimum possible and shrink their margins. This process is currently showing how low the bids can go under the constraint of competitive tenders. Many countries are now using such a way to deploy PV at the lowest possible cost. However, many believe such low bids are possible with extremely low capital costs, low components costs and a reduced risk hedging. Since they represented 4% of all PV installations in 2016 (but this should increase in the coming years), it is conceivable that they don't represent the fair PV price in all cases but showcases for super-competitive developers.

They have spread in the entire world over the last years and Europe didn't escape this with France using it for some market segments (above 100 kW in a simplified version and above 250 kW in all cases) and Germany is using them for utility-scale plants. In Latin America, Peru, Mexico, Brazil just to mention the most visible have implemented such tenders. In India, Chili, Mexico, the UAE and more recently Saudi Arabia, the bids are reaching extremely low levels, now close 30 USD/MWh in several cases and most probably below 20 USD/MWh when the tender in Saudi Arabia case. South Africa, Jordan, the USA and many others have implemented that system.

The tendering process that grants a PPA (which is nothing else than a FiT) can be a competitive one (in most cases) or simply an administrative procedure (Turkey). The competitive tenders can be organized as pay-as-bid (the best offers get the bid they have proposed) or pay-as-clear (the lowest one). It can be used to promote specific technologies (e.g. CPV systems in France in the past years) or impose additional regulations to PV system developers. It can propose a seasonal price. It can be technology specific (Germany, France, South Africa, etc.) or technology neutral (the Netherlands, Poland, UK). In this last case, PV is put in competition with other generation sources, with little success until now, but the situation could change in the coming years with PV becoming the cheapest source of electricity.

Spain innovates with a tender based not on the energy prices or capacities, but on the amount of necessary subsidies paid. In this auction process, bidders have to offer a discount on the standard value of the initial investment of a reference plant. The lowest bid winning the tender up to a predefined capacity level required. This tender also has the particularity to be technology neutral but welcomes only PV and wind.

TABLE 3: THE MOST COMPETITIVE TENDERS IN THE WORLD UNTIL Q4 2017

REGION	COUNTRY/STATE	USD/MWh
LATIN AMERICA & CARRIBEAN	MEXICO	20,57
LATIN AMERICA & CARRIBEAN	CHILE	21,48
EUROPE	PORTUGAL	38,8
EUROPE	GERMANY	38,8
EUROPE	SPAIN	38,8
SOUTH ASIA	INDIA	48
EUROPE	FRANCE	50,18

Germany exchange rate calculated 1 USD = 0,904 EURO

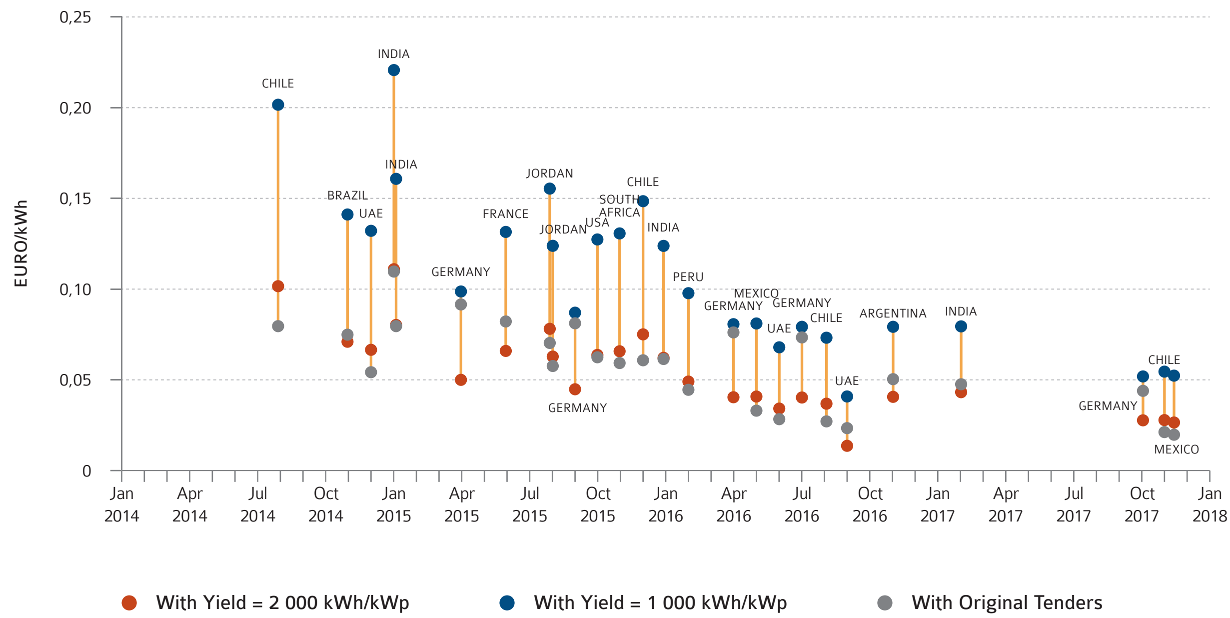
SOURCE IEA PVPS & OTHERS.

Additional Constraints

The ease of implementing FiT allows its use when PV is approaching competitiveness: Germany added a 90% cap in 2012 to the amount of electricity that could benefit from the FiT system, pushing for either selling the excess on the electricity market (at a quite low price, around 3 to 8 USDcents in 2016), or self-consumption. For systems where self-consumption is incentivized, a FiT can be used for the excess electricity not consumed locally and injected into the grid. This was done in Italy, but also in Germany or in Japan for systems below 10 kW.

The FiT payment can be adjusted to some parameters. Turkey for instance applies a premium for local content, on the top of the normal FiT. China, through its "top-runner" program favors high-efficiency technologies. In general the level of the FiT depends on

FIGURE 15: NORMALIZED PPA VALUE FOR RECENT TENDERS



SOURCE IEA PVPS, BECQUEREL INSTITUTE.

PV MARKET DRIVERS / CONTINUED

the segment but it can also evolve during the lifetime of the plant to follow some key indicators. FiT increasing over time for existing plants have been seen but this remains marginal.

In summary, FiT remains the most popular support scheme for all sizes of grid-tied PV systems; from small household rooftops applications to large utility-scale PV systems. The easiness of implementation continues to make it the most used regulatory framework for PV globally.

Feed-in Premium

In several countries, the FiT schemes are being replaced by feed-in premiums. The concept behind the premium is to be paid in addition to the wholesale electricity market price. Fixed and variable premiums can be considered. In Germany, the "direct marketing" of solar PV electricity is based on a Feed-in Premium (FiP) that is paid on top of the electricity wholesale market price in order to allow a remuneration slightly higher than the FiT, including a management premium. In the UK, the Contract for Difference scheme can be seen as a FiP that ensures a constant remuneration by covering the difference between the expected remuneration and the electricity market price. In China, FiPs are based on the coal power price.

Private PPAs

While FiT are paid in general by official bodies or utilities, looking for PPAs is compulsory in some countries. In Chile, for instance, the PV plants built in the northern desert of Atacama had to find PPAs with local industries in order to be beneficial (even if the low prices are now pushing for PV electricity sold into the electricity market). Such plants can be considered as really competitive since they rely on PPAs with private companies rather than official FiT schemes.

UPFRONT INCENTIVES

PV is by nature a technology with limited maintenance costs, no fuel costs but has a high upfront investment need. This has led some countries to put policies in place that reduce the up front investment in order to incentivize PV. This took place over the years in Austria, Australia, Belgium, Sweden, Japan, Italy and China; just mention some of them. These subsidies are, by nature, part of the government expenditures and are limited by their capacity to free up enough money. The 2017 tender in Spain could be considered to a certain extent as an upfront incentive.

Off-grid applications can use such financing schemes in an easier way, than for instance FiT that are not adapted to off-grid PV development.

TAX CREDITS

Tax credits can be considered in the same way as direct subsidies since they allow reducing the upfront PV investment. Tax credits have been used in a large variety of countries, ranging from Canada, the USA, to Belgium (until 2011), Switzerland, France, Japan, Netherlands and others. Italy uses a tax credit for small size plants. The debate was intense in the USA in 2015 whether or not extending the ITC (Investment Tax Credit) or to phase it out rapidly. Finally, the decision was taken to continue the current scheme at least until the end of the decade.

RENEWABLE PORTFOLIO STANDARDS AND GREEN CERTIFICATES

The regulatory approach commonly referred to as "Renewable Portfolio Standard" (RPS) aims at promoting the development of renewable energy sources by imposing a quota of RE sources. The authorities define a share of electricity to be produced by renewable sources that all utilities have to adopt, either by producing themselves or by buying specific certificates on the market. When available, these certificates are sometimes called "green certificates" and allow renewable electricity producers to get a variable remuneration for their electricity, based on the market price of these certificates. This system exists under various forms. In the USA, some states have defined regulatory targets for RES, in some cases with PV set-asides. In Belgium's regions, Romania and Korea, PV receives a specific number of these green certificates for each MWh produced. A multiplier can be used for PV, depending on the segment and size in order to differentiate the technology from other renewables. Korea, which used to incentivize PV through a FiT system moved to a RPS system in 2012 with a defined quota for PV installations. In Belgium, all three regions used the trading of green certificates that comes in addition to other schemes such as net-metering and in the past, direct capital subsidies and tax credits. The region of Brussels has introduced a specific correction factor that adapts the number of certificates in order to always get the return on investment in seven years. Romania uses a quota system, too, which however experienced a drop in the value of the green certificates in 2014. The UK was still using a system called ROC (Renewable Obligation Certificates) for large-scale PV in 2015, but it was replaced in 2016. It must be noted that Sweden and Norway share a joint, cross-border, Green Electricity Certificate system.

Since 2010, the European Union lives under a directive (law) that imposes on all European countries to produce a certain percentage of their energy consumption with renewable energy sources. This directive, sometimes known as the 20-20-20 (20% RES, 20% less green house gases and 20% energy efficiency) translates into a target of around 35% of electricity coming from RES sources in 2020, but with differentiated targets for all member states. It is expected that these targets will be met by 2020. This overarching directive does not impose utilities to meet these targets directly but allows European countries to decide on the best way to implement the directive and reach the target. This explains the variety of schemes existing in Europe and the very different official targets that have been defined for PV, depending on the country. For instance, Germany alone targets 52 GW of PV installations to be reached by the incentives defined in the EEG law. In 2014 a new directive defined 2030 objectives but these so far have not been made compulsory and the impact they will have on PV development in the coming years is still unknown. The relatively low level of ambition of these targets (27% of renewable energy by 2030) was heavily criticized and could be revised in the coming months or years.

CARBON TAXES

Some attempts have been made to impose carbon taxes as a way to support the development of renewables indirectly by putting an additional cost on CO_2 emitting technologies. The most important regulation has been the Emission Trading System in Europe (ETS) which aims at putting a price on the ton of CO_2. So far it has failed to really incentivized the development of PV or any other renewable source because of the low carbon price that came out of the system due to its flaws. Whether that system will be reviewed in the coming years is still unknown. Carbon pricing was in effect in Australia from 2011 until 2014. Canada is discussing the implementation of a carbon tax as this publication goes to press. In September 2015, China announced that its own cap-and-trade carbon program could enter into force in 2017. In general, the conclusion of an agreement during the COP21 in Paris in 2015 has signalled the start of a potential new era for carbon free technologies and the need to accelerate the transition to a carbon-free electricity system. In this respect, PV would greatly benefit from a generalized carbon price, pushing CO_2 emitting technologies out of the market.

SUSTAINABLE BUILDING REQUIREMENTS

With around 40% of PV installations occurring on buildings, the building sector has a major role to play in PV development. Sustainable building regulations could become a major incentive to deploy PV in countries where the competitiveness of PV is close. These regulations include requirements for new building developments (residential and commercial) and also, in some cases, on properties for sale. PV may be included in a suite of options for reducing the energy footprint of the building or specifically mandated as an inclusion in the building development.

In Korea, the NRE Mandatory Use for Public Buildings Programme imposes on new public institution buildings with floor areas exceeding 1 000 square meters to source more than 10% of their energy consumption from new and renewable sources. In Denmark, the national building code has integrated PV as a way to reduce the energy footprint. Spain used to have some specific regulations but they never really succeeded in developing this part of the PV market. In all member states of the European Union, the new Energy Performance in Buildings Directive (EPBD) will impose to look for ways to decrease the local energy consumption in buildings, which could favor decentralized energy sources, among which PV appears to be the most developed one, from 2020 onwards.

Two concepts should be distinguished here:

- Near Zero Energy Buildings (reduced energy consumption but still a negative balance);
- Positive Energy Buildings (buildings producing more energy than what they consume).

These concepts will influence the use of PV systems on building in a progressive way, now that competitiveness has improved in many countries.

SELF-CONSUMPTION SCHEMES

With around 25% of distributed PV installations in 2016, it seems logical that a part of the PV future will come from its deployment on buildings, in order to provide electricity locally. Even if distributed PV applications are declining for years, the declining cost of PV electricity puts it in direct competition with retail electricity provided by utilities through the grid and several countries have already adopted schemes allowing local consumption of electricity. These schemes are often referred to as self-consumption or net-metering schemes.

These schemes simply allow self-produced electricity to reduce the PV system owner's electricity bill, on site or even between distant sites (Mexico, Brazil, France). Various schemes exist that allow compensating electricity consumption and the PV electricity production, some compensate real energy flows, while others are compensating financial flows. While details may vary, the bases are similar.

In order to better compare existing and future self-consumption schemes, the IEA PVPS published a comprehensive guide to analyze and compare self-consumption policies. This "Review of PV Self-Consumption Policies" proposes a methodology to understand, analyze and compare schemes that might be fundamentally diverse, sometimes under the same wording. It also proposes an analysis of the most important elements impacting the business models of all stakeholders, from grid operators to electric utilities.

Self-Consumption

Pure self-consumption exists in several countries and in particular in Germany. For instance, electricity from a PV system can be consumed by the PV system owner, reducing the electricity bill. The excess electricity can then benefit from the FiT system. Until 2012, Germany incentivized self-consumption by granting a bonus above the retail price of electricity. This bonus was increased once the threshold of 30% of self-consumed PV electricity was passed. With the decline of FiT levels, these are now below the price of retail electricity and the bonus has disappeared. Self-consumption implies revenues coming from savings on the electricity bill. These revenues can be decreased if grid taxes and some levies are to be paid in any case by the prosumer, on the self-consumed electricity. Even if these measures appear rather unfair for prosumers and tend to show how fierce the opposition from conventional electricity stakeholders could be, they were applied in 2015 in some countries, such as Germany, Spain or Belgium.

Excess PV Electricity Exported to the Grid

Traditional self-consumption systems assume that the electricity produced by a PV system should be consumed immediately or within a 15 minutes timeframe in order to be compensated. The PV electricity not self-consumed is therefore injected into the grid.

Several ways to value this excess electricity exist today:

- The lowest remuneration is 0: excess PV electricity is not paid while injected (Spain, Thailand pilot project);

UPFRONT INCENTIVES / CONTINUED

- Excess electricity gets the electricity market price, with or without a bonus (Germany);
- A FiT remunerates the excess electricity (Japan below 10 kW, Germany) at a predefined price. Depending on the country, this tariff can be lower or higher than the retail price of electricity.
- Price of retail electricity (net-metering), sometimes with additional incentives or additional taxes (Belgium, USA).

A net-metering system allows such compensation to occur during a longer period of time, ranging from one month to several years, sometimes with the ability to transfer the surplus of consumption or production to the next month(s). This system exists in several countries and has led to some rapid market development in 2012 in Denmark and in The Netherlands until now. In Belgium, the system exists for PV installations below 10 kW. In USA, 38 states plus the District of Columbia and Puerto Rico have implemented net-metering policies. In 2013, the debate started in the USA about the impact of net-metering policies on the financing of utilities, especially vertically integrated distribution actors. The conclusion so far was to either do nothing until the penetration of PV would reach a certain level (California) or to impose a small fee (Arizona) to be paid by the prosumer. Several emerging PV countries have implemented net-metering schemes or will do so in 2016 (Israel, Jordan, UAE (Dubai) and Chile). Portugal is setting up a net-billing scheme.

The main question that developed in 2016 concerns the extension of self-consumption concepts to distant production and consumption sites. As already mentioned above, this has been tested in some countries, while the question of the remuneration of the grid remains central. Many start to consider the "virtual self-consumption" or "virtual net-metering" as a way to ease the integration of PV in the distribution grids, while solving the acute question of the self-consumption ratio in residential and commercial buildings. Given the complex questions that such schemes create, especially with regard to the use of the grid, the legal aspects related to compensating electricity between several meters and the innovative aspect of the scheme, it is believe it can ease the integration of PV into the energy transformation, support the development of smarter buildings and accelerate the transition to electric vehicles.

Virtual Self-Consumption

While self-consumption could be understood as the compensation of production and consumption locally, it offers innovative alternatives once it becomes collective or virtual. Collective self-consumption allows to share electricity between several users, in general behind the meter. Virtual sel-consumption expands to delocalized consumption and production and opens a wide range of possibilities involving ad hoc grid tariffs. In that respect, prosumers at district level would pay less grid costs that prosumers at regional or national level. Such policies have been tested in some cases in some countries as seen above but are still considered by many policymakers as too innovative. Without legislation, utilities can already propose (as in Austria or Switzerland) innovative products mixing PV installations, PV investment and virtual storage. This evolution will be scrutinized in the coming years.

Other Direct Compensation Schemes

While the self-consumption and net-metering schemes are based on an energy compensation of electricity flows, other systems exist. Italy, through its Scambio Sul Posto (net-billing scheme), attributes different prices to consumed and the electricity fed into the grid. In Israel, the net-billing system works on a similar basis.

Grid Costs and Taxes

The opposition from utilities and in some cases grid operators (in countries where the grid operator and the electricity producers and retailers are unbundled as in Europe) grew significantly against net-metering schemes. While some argue that the benefits of PV for the grid and the utilities cover the additional costs, others are pledging in the opposite direction. In Belgium, the attempt of adding a grid tax to maintain the level of financing of grid operators was stopped by the courts and then reintroduced. While these taxes were cancelled later, they reveal a concern from grid operators in several countries. In Germany, the debate that started in 2013 about whether prosumers should pay an additional tax was finally concluded. The EEG surcharge will be paid partially on self-consumed electricity. In Israel, the net-billing system is accompanied by grid-management fees in order to compensate the back-up costs and the balancing costs. In general, several regulators in Europe are expected to introduce capacity-based tariffs rather than energy-based tariffs for grid costs. This could change the landscape in which PV is playing for rooftop applications and delay its competitiveness in some countries.

MARKET BASED INCENTIVES

Most countries analysed here have a functional electricity market where at least a part of the electricity consumed in the country is traded at prices defined by the laws of electricity's supply and demand. In order to further integrate PV into the electricity system, Germany set the so-called "market integration model" in 2012.

A limitation at 90% (for systems between 10 kW and 1 MW) of the amount of PV electricity that can benefit from the FiT scheme has been introduced in Germany in 2012. It has pushed PV system owners to sell the remaining PV electricity on the market. This can be done at a fixed monthly price with a premium. In addition, the German law allows selling PV electricity directly on the market, with variable, market-based prices, the same management premium and an additional premium to cover the difference with FiT levels, with the possibility to go back and forth between the FiT scheme and the market. At the end of 2016, an average 6 GW of PV (out of 41 GW installed) were traded on a regular basis on the electricity market.

Market premiums can use existing financial instruments: see the FiP paragraph above. In several countries, it starts to be recognized that the current organization of electricity markets will have to be revised in depth in order to allow variable renewables and especially PV to integrate them.

SOFT COSTS

Financial support schemes have not always succeeded in starting the deployment of PV in a country. Several examples of well-designed FiT systems have been proven unsuccessful because of inadequate and costly administrative barriers. Progress has been noted in most countries in the last years, with a streamlining of permit procedures, with various outcomes. The lead time could not only be an obstacle to fast PV development but also a risk of too high incentives, kept at a high level to compensate for legal and administrative costs.

Soft costs remain high in several countries but prices have started to go down in some key markets, such as Japan or the USA. In these two markets for instance, system prices for residential systems continue to be significantly higher than prices in key European markets. While the reason could be that installers adapt to the existing incentives, it seems to be more a combination of various reasons explaining why final system prices are not converging faster in some key markets. Moreover, it seems that additional regulations in some countries have a tendency to increase the soft costs compared to the best cases. This will have to be scrutinized in the coming years to avoid eating up the gains from components price decrease.

INNOVATIVE BUSINESS MODELS

Until recently, a large part of the PV market was based on traditional business models based on the ownership of the PV plant. For rooftop applications, it was rather obvious that the PV system owner was the owner of the building. But the high upfront capacity requirements are pushing different business models to develop, especially in the USA, and to a certain extent in some European countries. PV-as-a-service contributes significantly to the residential US market for instance, with the idea that PV could be sold as a service contract, not implying the ownership or the financing of the installation. These business models could deeply transform the PV sector in the coming years, with their ability to include PV in long term contracts, reducing the uncertainty for the contractor. Such business models represent already more than 50% of the residential market in the USA, and some German, Austrian, Swiss and Swedish utilities are starting to propose them, as we will see below. However, the US case is innovative by the existence of pure-players proposing PV (such as SolarCity, Vivint...) as their main product. Since it solves many questions related to the financing, the operations and reduces the uncertainty on the long term for the prosumer, it is possible that such services will develop in a near future, as the necessary developments that will push the distributed PV market up.

GRID INTEGRATION

With the share of PV electricity growing in the electricity system of several countries, the question of the integration to the electricity grid became more acute. In China, the adequacy of the grid remains one important question that pushed the government to favour more the development of decentralized PV in the future rather than large utility-scale power plants. In Europe or Australia, specific grid codes have been adapted for PV and more will come. In Mexico, specific grid requirements have in some cases be imposed to bidders in tendering processes. In any case, grid integration policies will become an important subject in the coming years, with the need to regulate PV installations in densely equipped areas.

ELECTRICITY STORAGE

In the current stage of development, electricity storage remains to be incentivized to develop. While some iconic actors are proposing trendy batteries, the real market remains more complex and largely uncompetitive without financial support.

In Germany, since 2013, the KfW is running a market stimulation program to boost the installation of local stationary storage systems in conjunction with small PV systems below 30 kWp.

Some US states have developed programs for storage development. In particular, California has introduced the Self-Generation Incentive Program that offers rebates for "advanced energy storage". These incentives varies between 0,32 and 0,45 USD/Wh. The current Hawaiian self-consumption program provides a self-supply option, where PV owners can gain preferential permitting treatment by consuming all PV onsite. In this case no value is given to exported generation. In the French overseas' departments (including Corsica), a call for tenders for 50 MW of PV systems above 100 kW with storage has been set proposed in 2015, aiming at increasing the grid stability. In Japan, demo projects have been started on the grid as well. Projects to install storage batteries are also increasing but they are limited by subsidies since the cost remains high. Storage batteries for residential applications are part of a subsidy program to accelerate the development of net zero energy houses. For this subsidy program, five rounds of public invitation were carried out, which received 6 368 applications in total. Other subsidy for storage batteries are available in Japan. In Australia, storage incentives were offered by the City of Adelaide and the City of Melbourne in 2015. The City of Adelaide provides 50% of the cost of batteries up to a value of AUD 5 000, plus up to a further AUD 5 000 for 20% of the price of a PV system. Many other countries are incentivizing battery storage. However the trend is not clear yet whether battery storage will be supported for improving local self-consumption or to reduce the pressure on weak grids. The benefits of energy storage at system level appear clearly, for stability and generation adequacy. But at consumer level, stationary batteries enter in direct competition with advanced virtual self-consumption systems but also electric vehicles. Few (or no) countries propose today a clear vision of the future integration of decentralized storage in future electricity grids, taking into account electric mobility, electrification of heating and cooling and the possibilities that digitalization offers to implement innovative business models for self-consumption.

ELECTRICITY STORAGE / CONTINUED

CONCLUSION

Once again in 2016, the most successful PV deployment policies based themselves on FiT policies or direct incentives (including tax breaks). The growth in China (FiT+direct incentives) and the USA (tax breaks, net-metering), but also the high market level in Japan shows how important these incentives remain. Other support measures remained anecdotic in the PV development history. The projects granted through tenders have increased to reach more than 4% of the total and more are expected to come in the coming years.

With declining cost of PV electricity generation, the question of alternative support schemes has gained more importance in several countries. The emergence of schemes promoting the self-consumption of PV electricity is now confirmed and some countries rely on these schemes only to ensure PV deployment. Instead of national support schemes, several countries favour private contracts to purchase PV electricity (PPA) from utility-scale power plants, while in several European countries the same plants are being banned from official support schemes.

In parallel the difficulties of the distributed market which remained stable in the last five years concentrates the growth of the PV market in the utility-scale segment. However, the major outcome of 2015 consists again in the widespread use of tendering in emerging PV markets that are driving prices very low in all parts of the world.

BIPV incentives have lost ground, with few countries maintaining adequate support schemes to favour their development (France and Switzerland) but a market for architectural BIPV is developing slowly in Europe and to a lesser extent in Japan, Korea and the USA.

Policies targeting the entire electricity system remain marginal, with several countries running RPS systems but few with real PV obligations.

TABLE 4: OVERVIEW OF SUPPORT SCHEMES IN SELECTED IEA PVPS COUNTRIES[1]

COUNTRY	DIRECT CAPITAL SUBSIDIES	GREEN ELECTRICITY SCHEMES	PV-SPECIFIC GREEN ELECTRICITY CITY SCHEMES	RENEWABLE PORTFOLIO STANDARDS	PV SPECIAL TREATMENT IN RPS	FINANCING SCHEMES FOR PV INVESTMENT FUND	TAX CREDITS	NET-METERING/NET-BILLING/SELF-CONSUMPTION INCENTIVES	COMMERCIAL BANK ACTIVITIES	ELECTRICITY UTILITY ACTIVITIES	SUSTAINABLE BUILIDING REQUIREMENTS
AUSTRALIA	Used	Used	Used	Used		Used		Used	Used	Used	Used
AUSTRIA		Used						Used			Used
BELGIUM	Used	Used	Used				Used	Used			
CANADA	Used	Used						Used			Used
CHINA	Used	Used		Used			Used	Used			
DENMARK								Used		Used	Used
FINLAND	Used						Used	Used		Used	Used
FRANCE							Used		Used		Used
GERMANY	Cancelled	Cancelled				Cancelled		Used	Cancelled		
ISRAEL		Used	Used					Used			
ITALY							Used	Used	Used	Used	Used
JAPAN	Cancelled	Used		Used		Used	Used	Used	Used	Used	Used
KOREA	Used			Used			Used		Used	Cancelled	Cancelled
MALAYSIA		Used	Used				Used	Used	Used	Used	Used
MEXICO								Used			
NETHERLANDS		Used						Used			
NORWAY	Used	Used		Cancelled							
PORTUGAL								Used	Used		
SPAIN									Used		Used
SWEDEN	Used	Used		Cancelled			Used	Used		Used	Used
SWITZERLAND	Used	Used	Used				Used	Used	Used	Used	Used
THAILAND	Used								Used		
TURKEY	Used							Used			
USA	Used	Used		Used	Used	Used	Used	Used	Used	Used	Used

■ This support scheme has been used in 2016

■ This support scheme has been cancelled in 2016

four

TRENDS IN THE PV INDUSTRY

This chapter provides a brief overview of the upstream part of the PV manufacturing industry. It is involved in the production of PV materials (feedstock, ingots, blocks/bricks and wafers), PV cells, PV modules and balance-of-system (BOS) components (inverters, mounting structures, charge regulators, storage batteries, appliances, etc.). The downstream part of the PV sector during 2016, including development and maintenance is also briefly presented. This chapter is intending to provide a summarized overview of the PV industry: more detailed information on the PV industry in each IEA PVPS member country can be found in the relevant National Survey Reports.

A national overview of PV material production and cell/module manufacturing in the IEA PVPS countries during 2016 is presented in Annex 3 and is directly based on the information provided in the National Survey Reports of IEA PVPS member countries.

As presented above in this report, the global PV installed capacity reached 76 GW in 2016 achieving a 50% year on year growth. The production of polysilicon, ingots, wafers PV cells and modules also increased to record levels. The Chinese market influenced the entire global PV production in a sharper way than the previous year(s). In 2016, the first half of the year was extremely bullish with more than 20 GW of PV systems newly installed in China due to a rush for securing the higher FIT level granted until the end of June. The same rush was visible in the first months of 2017 and will lead to the same results. The third quarter in China in 2016 remained sluggish and some further PV module price decrease was observed, bringing module prices to new unseen lows and putting the pressure on the entire industry. The market prices of silicon feedstock, PV cells and modules continued to be on declining trends in 2016. This resulted in a new significant reduction of the initial cost of PV systems.

Trade conflicts in some regions continued to affect the strategies of PV manufacturing sites. Major PV module manufacturers started production outside of China, mainly in countries such as Malaysia, Thailand and Vietnam. Under this circumstance, the acceleration of the downstream business continued throughout the year, powered by lowered prices.

THE UPSTREAM PV SECTOR (MANUFACTURERS)

This section reviews some trends of value chain of crystalline silicon technology and thin-film PV technologies. While PV system consists of various steps and materials as shown in Figure 16, this section focuses on the key trends of polysilicon, ingot/wafer/cells and PV modules (crystalline silicon and Thin film PV) as well as inverters.

Polysilicon Production

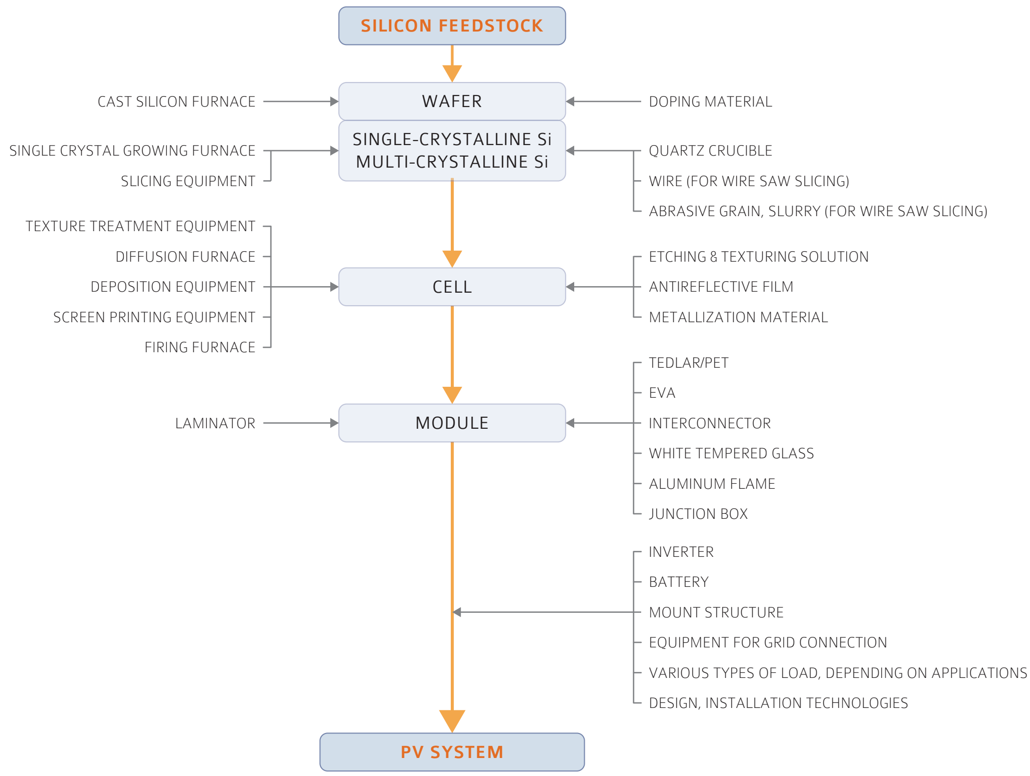
Wafer-based crystalline silicon technology remains dominant for producing PV cells. In that respect, this section focuses on the wafer-based production pathway. Although some IEA PVPS countries reported production of feedstock, ingots and wafers, the pictures from the National Survey Reports of these sections of the PV industry supply chain are not complete and consequently this section provides more background information on the upstream part of the PV value chain thanks to additional information.[1]

It is estimated that polysilicon production for solar cells increased from 310 000 tons in 2015 to 360 000 tons in 2016.

footnote 1 Source: RTS Corporation from Japan.

THE UPSTREAM PV SECTOR / CONTINUED

FIGURE 16: PV SYSTEM VALUE CHAIN (EXAMPLE OF CRYSTALLINE SILICON PV TECHNOLOGY)



SOURCE IEA PVPS & OTHERS.

Polysilicon production for semiconductors remained stable around 30 000 ton in 2016. Thus, the amount of polysilicon for solar PV applications accounted for more than 90 % of total production of polysilicon in 2016.

As of the end of 2016, global manufacturing polysilicon capacity reached around 490 000 ton/year. Tier 1 producers accounted for 75% of the global production capacities in 2016, a 5% increase compared to previous year. As well as in 2015, new plans for capacity expansion and new manufacturing projects continued to be announced in 2016 driven by gap between demand and production capacity. In 2016, 44 000 tons of new capacity were reported. It is estimated that global polysilicon production capacity in 2017 will reach 546 000 ton/year. Production capacity enhancement plans continued to be reported in 2017. It is noted that a movement toward consolidation was observed in 2016. GCL Poly Energy acquired assets of a failed polysilicon producer in US. In May 2017, Korean OCI acquired the Malaysian polysilicon plant from Tokuyama from Japan. In 2016, the top 3 manufacturers, Wacker Chemie (Germany), GCL-Poly Energy (China) and OCI supplied around half of global polysilicon demand.

In 2016, it is estimated that about 410 000 tons of polysilicon was used for crystalline silicon solar cells considering that 5,4 g of polysilicon are used for each W of solar cell (the lowest case established itself at around 4 g per W).

The polysilicon spot price in the beginning of 2016 was 13 USD/kg. It increased to 17 USD/kg in June 2016 due to strong demand in China. The price dropped to the record low level, 12,7 USD/kg in October 2016 affected by the contraction of the Chinese market in the third quarter. In the end of the year, the price recovered to the level of 15 USD/kg. While spot prices showed a clear decline, some PV manufacturers procured polysilicon at higher prices under long term contracts signed when polysilicon supply was tight (2006 to 2010). These contracts still produce impacts on PV module manufacturing costs for some manufacturers. Some legal disputes about long term contracts between cell/module companies and polysilicon producers continued to be reported.

Most of major polysilicon manufacturers adopt conventional technologies such as Siemens and FBR (Fluidized bed reactor) processes, which are used to supply polysilicon for the semiconductor industry. Production efficiency has progressed and energy consumption of the reduction process in 2016 was between 50 to 55 kWh/kg. Reduction processes utilizing advanced technologies decreased energy consumption to 40 kWh/kg. In comparison to around 120 kWh/kg in 2009, an average 12% per year decrease was achieved.

The FBR process requires less electricity than the Siemens process and produce granular polysilicon that can be efficiently packed in the crucibles with polysilicon blocks. To reach a cost advantage, some of the major companies are planning to enhance their capacities with the FBR process. Another lower cost process is the metallurgical process that directly enables to produce from metallic silicon. Silicor Materials, USA announced it concluded financing for constructing a 19,000 ton/year plant with metallurgical process in Iceland.

As well as in the previous year, the major polysilicon producing countries among IEA PVPS countries were China, Germany, South Korea, USA, Japan, Malaysia and Norway in 2016. China continued to be the largest producer and consumer of polysilicon in the world. China reported that it produced 194 000 tons of polysilicon with 210 000 ton/year of production capacity, a 17,6% increase over the 165 000 tons from 2015, accounting for about an half of the total global production. China reported that it consumed 330 000 tons of polysilicon for solar cells and imported around 136 000 tons of polysilicon produced outside of China, mainly from Germany, Korea and Malaysia where anti-dumping duties the government imposes are free or lower. The largest producer in China was GCL-Poly Energy (Jiangsu Zhongneng Polysilicon Technology Development). it possesses a 75 000 ton/year capacity and produced 69 345 tons in 2016. Second largest producer, TBEA Solar produced 22 800 tons. The main other major manufacturers in China are China Silicon and Daqo New Energy. The pressure on the price of polysilicon observed in the fourth quarter lead to a restart of operation of the polysilicon plants in China. It is reported that the number of Chinese polysilicon producers in operation increased from 13 companies in 2015 to 17 companies in 2016.

South Korea reported 82 000 ton/year of production capacity in 2016. The largest producer OCI obtained the Malaysian polysilicon plant from Tokuyama of Japan in May 2017 and its total production capacity home and abroad reached 80 000 tons/year. It produced 60 000 tons of polysilicon in 2016. Other reported Korean producers are Hanwha Chemical, Hankook Silicon and SMP (Joint venture of LOTTE Fine Chemical and GCL-Poly Energy of China).

Germany has more than 60 000 ton/year of domestic polysilicon manufacturing capacity. Wacker Chemie has 80 000 ton/year of production capacity in Germany and USA. It is estimated that Wacker shipped more than 70 000 tons in 2016 and the company reached the number 1 position as polysilicon producer in the world in 2016.

The USA increased their polysilicon manufacturing capacity at 90 000 ton/year including a plant in Tennessee operated by Wacker Chemie, Germany. Other major US manufacturers are Hemlock Semiconductor and REC Silicon. SunEdison filed for bankruptcy in April 2016 and sold its polysilicon assets to GCL-Poly Energy of China. The polysilicon production in the USA showed a further decrease in 2016 from 34 853 tons in 2015 to 29 624 due to Anti-dumping Duties (ADs) imposed in China and the bankruptcy of Sun Edison.

In Japan, Tokuyama produced 16 300 tons of polysilicon in Japan and Malaysia including the production for semiconductors. The company sold its Malaysian polysilicon plant with 20 000 ton/year capacity to OCI, Korea as mentioned above. Canada, the USA and Norway reported activities of polysilicon producers working on metallurgical process aiming at lowering the production cost. Silicor Materials in USA owns a plant in Canada and is building a manufacturing one in Iceland. Elkem Solar in Norway produced 6 500 tons of polysilicon in 2016 as well as in 2015.

Ingot & Wafer

To produce single-crystalline silicon (sc-Si) ingots (also known as mono-crystalline) or multi-crystalline silicon (mc-Si) ingots, the basic input material consists of highly purified polysilicon. The ingots need to be cut into bricks or blocks and then sawn into thin wafers. Conventional silicon ingots are of two types: Single-crystalline and multi-crystalline. The first type, although with different specifications regarding purity and specific dopants, is also produced for microelectronics applications, while mc-Si ingots are only used in the PV industry.

Ingot producers are in many cases producers of wafers. In addition to major ingot/wafer manufacturers, some PV modules manufacturers such as Jinko Solar (China), JA solar (China), Yingli Green Energy (China), REC Solar (Singapore), SolarWorld (Germany), Panasonic (Japan), Kyocera (Japan) and more also manufacture silicon ingots and wafers for their in-house uses. This situation makes it difficult to track down the entire picture of ingots and wafers production. Due to the cost pressure, some of the major PV module manufacturers that established vertically integrated manufacturing are now procuring wafers from specialized manufacturers because of cost and quality advantages. In 2016, it is estimated that over 75 GW of crystalline silicon wafers were produced. The total global wafer manufacturing capacity was estimated to be around 100 GW/year at the end of the year 2016.

In 2016, China produced 64,8 GW of solar wafers, achieving a 86% share in the global wafers production. China increased its production capacity of wafer from 64,3 GW/year in 2015 to 81,9 GW/year in 2016. As during the previous year, GCL-Poly Energy was the largest producer in China (and globally) and it produced 17,33 GW with 20 GW/year of manufacturing capacity in 2016.

Compared to China, the manufacturing capacities in other IEA PVPS countries remain small: Korea (2,38 GW/year), Japan (> 1,2 GW/year). Malaysia, Norway and the USA also reported some ingots/wafers manufacturing activities. Outside IEA PVPS countries, the Chinese Taipei/Taiwan island remains a major actor for solar wafers production. Around 10 companies including solar cell manufacturers have more than 6,5 GW of yearly production capacity in total. The Norwegian company, REC Solar produces solar wafers for its own use in its Singaporean factory with about 1 GW of annual capacity.

The mc-Si wafers spot price continued to decline until the third quarter in 2016 and then showed a slight recovery in the fourth quarter of the same year. Reported price in the beginning and end

THE UPSTREAM PV SECTOR / CONTINUED

of 2016 ranged from 0,62 USD/piece to 0,77 USD/piece. sc-Si price has decreased from 0,89 USD/piece in January 2015 to 0,77 USD/piece in December of the same year. While the supply and demand balance was relatively tight throughout of 2016, spot prices dropped. The decline is mainly caused by the strong pressure from manufacturers of PV modules due to the price downward trends and it is assumed that any significant price recovery might be difficult in the circumstances experienced at the end of 2016.

It is notable that the price difference of mc- and sc-wafers has been narrowing due to improvement of mc-Si wafer quality and the PERC process. More than 20,1% of conversion efficiency is reported using advanced mc-Si wafers from GCL Poly-Energy (China) and Sino-American Silicon (Taiwan). Jinko Solar (China) established a 21,6% of conversion efficiency with mc-Si PERC cells in October 2016. Trina Solar (China) also reported that it produced mc-Si solar cell with 20,16% of conversion efficiency in a real production process in 2016.

The paths to lowering wafers' production costs are driven mainly by larger-size crucibles for mc-Si wafers (G7 generation crucible for 1 000 kg charging) and improvement of seed-crystals to reduce process time and increase yield. Utilization of diamond wire sawing (DWs) has been advanced by its efficiency and cheaper process cost with smaller kerf loss. While DWs were mainly used for sc-Si, the adoption of DWs for mc-Si has been accelerated by price decrease of DWs and reactive Ion etching (RIE) or Black Silicon technologies for texturizing.

Startup companies in the USA and Europe are developing new processes to manufacture wafers without conventional ingot growing and wire-sawing process. 1366 Technologies in USA announced that it achieved 20,3% of conversion efficiency with PERC solar cell using its kerfless wafers directly processed melting polysilicon. IMEC (Belgium) announced it achieved 22,5% of conversion efficiency with solar cells using Direct Gas to Wafer Technology by Crystal Solar (USA). NexWafe in Germany is working on Epiwafer technologies aiming at commercialization in the coming years.

Photovoltaic Cell and Module Production

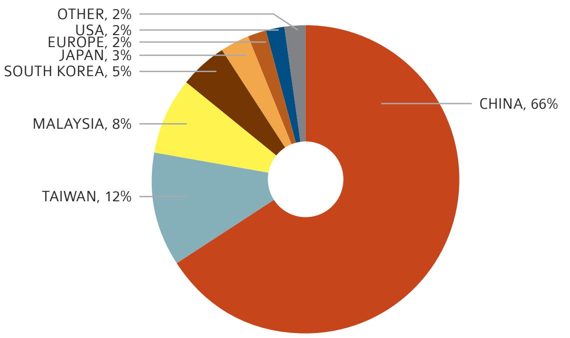
The global PV cells (crystalline silicon PV cells and thin-film PV cells) production is estimated to be around 77 GW during the year 2016. As well as during the previous year, China reported the largest production of PV cells: 51,2 GW of solar cells were produced in China in 2016, a 24% increase over the previous year (41 GW in 2015).

As shown in Figure 17, China's production volume accounts for 66% of the world total. IEA PVPS countries producing PV cells are China, Malaysia, South Korea, Japan, Germany, and USA. Major non-IEA PVPS countries manufacturing solar cells are Taiwan, Philippines, Singapore and India. Taiwan has more than 13 GW/year of production capacity, the second largest number in the world following China.

Figure 18 shows the evolution of PV cells production volumes in selected countries. China ranked number 1 in the world. Taiwan produced about 10 GW and kept the second position in the same way as in 2015. Malaysia and South Korea showed a notable increase of cells production. Malaysia produced close to 6 GW of solar cells (crystalline Si and CdTe) with around 8 GW of production capacity. The country hosts factories of major manufacturers including SunPower (US), Panasonic (Japan), Jinko Solar (China), Hanwha Q-cells (South Korea), JA solar (China), COMTEC (China) and First Solar (USA). In South Korea, Hanwha Q-cells' investment for production capacity contributed to the growth.

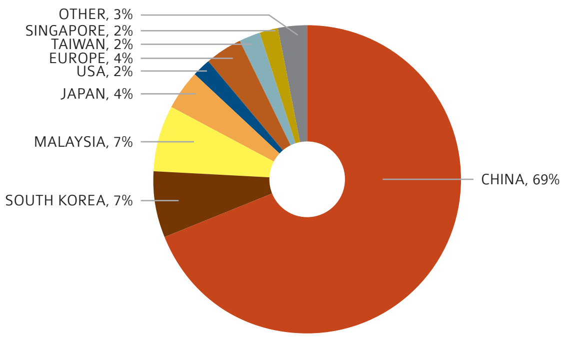
Among the crystalline silicon solar cells, mc-Si accounts for almost 80% of crystalline silicon technology. As mentioned in the wafer section, the announcement of the increase of PERC cells production lines continues from major manufacturers. Shift to PERC cells from Al-BSF cells progressed in 2016 and the share of PERC cells could be estimated around 15% at the end of 2016. To achieve higher efficiencies, improved passivation process for PERC or PERT structures, thinner electrodes, adoption of 4 or more bus bars, multi-busbars or wiring without busbars are applied to cells. For higher efficiency solar cells, companies

FIGURE 17: SHARE OF PV CELLS PRODUCTION IN 2016



SOURCE IEA PVPS, RTS CORPORATION.

FIGURE 18: SHARE OF PV MODULE PRODUCTION IN 2016



SOURCE IEA PVPS, RTS CORPORATION.

continued to invest in R&D. In 2016, Kaneka from Japan achieved a record efficiency for n-type sc-Si cell: 26,33% with heterojunction and back-contact technologies.

Global PV modules production (crystalline silicon PV and thin-film PV) is estimated around 80 GW in 2016. More than 90% of PV modules were produced in IEA PVPS member countries. As shown in Figure 15, China is the largest producing country with 53,7 GW of PV modules produced in 2016, accounting for 69% of global PV module production. Following China, South Korea and Malaysia produced close to 6 GW of PV modules each. Other major IEA PVPS countries reporting PV modules production capacity in 2016 are Japan, Germany and the USA but also other countries at a lower level, such as Australia, Austria, Canada, Mexico, Denmark, France, Italy, Finland, Sweden, Thailand and Turkey.

The largest PV module producer in 2016 was Jinko Solar that produced 5,7 GW. The second largest company was Trina Solar with 5,5 GW of production. JA Solar (4,7 GW), Canadian Solar (4,5 GW) and GCL Systems (3,8 GW) followed. As during the previous year, major Chinese companies established production plants outside of China in Turkey, Malaysia, Thailand, Vietnam and Brazil in order to avoid ADs implemented by trade conflicts or simply meet domestic content requirements. As a result, PV modules production bases have been more and more diversified. Trina Solar inaugurated its factory in Thailand in March 2016. JA Solar is also planning to invest into a production facility in Thailand. In non-IEA PVPS members, major producing countries were Singapore, Taiwan, the Philippines, Vietnam, India, and Poland. Plans for production were announced in Algeria, Brazil, Morocco, Ghana, Saudi Arabia, and much more countries.

PV modules have seen products with a higher power output that have been released using high efficiency solar cells or half-cut solar cells to increase their power. Other technologies such as light trapping with glass coatings, encapsulants with wavelength conversion functions are also used. PV modules using overlapped solar cells without ribbons are developed by several companies. other new products comprise double glass PV modules with 30 years warrantee or bifacial PV modules for an increased yield, specific PV modules for 1 500 V connections, light-weight crystalline silicon PV modules used chemical tempered glass or polymers, etc.

The average spot price of PV modules at the beginning of 2016 started at 55 USDcent/W and rapidly decreased until the end of second quarter. During the third quarter, the price dropped below 40 USD cent/W and the price at the end of the year reached 36 to 40 USDcent/W. It is expected that with rapidly decreasing margins, the consolidation of PV modules manufacturers will continue as long as capacity exceeds demand.

Figure 15 shows the trends of estimated global production capacity and production. The estimated global PV manufacturing capacity increased from 94 GW in 2015 to 105 GW in 2016. The largest increase of production capacity is reported in China. According to the Chinese Photovoltaic Industry Association (CPIA), China's domestic PV modules production capacity increased from 69 GW/year in 2015 to 79 GW/year in 2016. The utilization rate in 2016 was 73% and increased by 6% from the previous year. Utilization of PV modules capacity showed some improvement. Most of Tier 1 PV modules manufacturers have plans for manufacturing capacity enhancement as they foresee further growth in the global PV market. The enhancement of manufacturing capacities is not only achieved by building new factories but also by the acquisition of closed factories or the establishment of joint ventures with other companies. The increase in capacities is also coming marginally from the increase of efficiencies but this plays a minor role.

It is estimated that 4,9 GW of thin film PV modules were produced in 2016, accounting for 6% of total PV modules production (see Figure 17). Thin-film PV modules are mainly produced in Malaysia, Japan, USA, Germany and Italy as it was the case during the previous year. The largest thin-film producer remains First Solar of USA. The company produced 3 GW of CdTe Thin-film PV modules in its factories in the USA and Malaysia in 2016. It ranked seventh in the global PV module production. It is notable that conversion efficiencies of CdTe PV modules has been improved. The company achieved 22,1% of conversion efficiency with its laboratory made module. The second largest thin-film PV manufacturer is Solar Frontier of Japan. It produced 910 MW of CIS modules in 2016. Other thin-film manufacturing activities were reported from Germany, Italy, China and Thailand, while production volumes remained relatively small.

As well as previous years, efforts on R&D and commercialization of CIGS PV modules are continuously reported in a number of IEA PVPS member countries aiming at higher conversion efficiencies, higher throughput and larger sizes. To compete with crystalline silicon technology, First Solar decided to introduce large-size CdTe modules earlier than originally planned. Flexible or light-weight PV modules are also part of R&D efforts. BIPV applications are expected to become a major market for flexible PV modules. Some thin-film PV modules manufacturers shifted to Hetero Junction crystalline Silicon solar cell utilizing their thin-film silicon technology. Japan's Kaneka is one of the example and 3SUN, an Italian thin-film PV modules manufacturer also announced their business plan to produce HJT cell. Hevel Solar, a Russian company also announced its plan for HJT cells production.

In 2016, activities on concentrator PV (CPV) cells/ modules were reported by several IEA PVPS member countries. This technique is mainly based on specific high-efficiency multi-junction PV cells using group III-V materials, such as GaAs, InP, etc. Germany, USA, France, Japan and Spain are active in R&D of these high efficiency solar cells. While conversion efficiency of CPV modules has been improving, CPV system seems to less cost competitive and have difficulties competing with conventional PV systems. Because of the withdrawal of several CPV companies from the business, most activities related to CPV technologies shifted back to R&D and demonstrators.

THE UPSTREAM PV SECTOR / CONTINUED

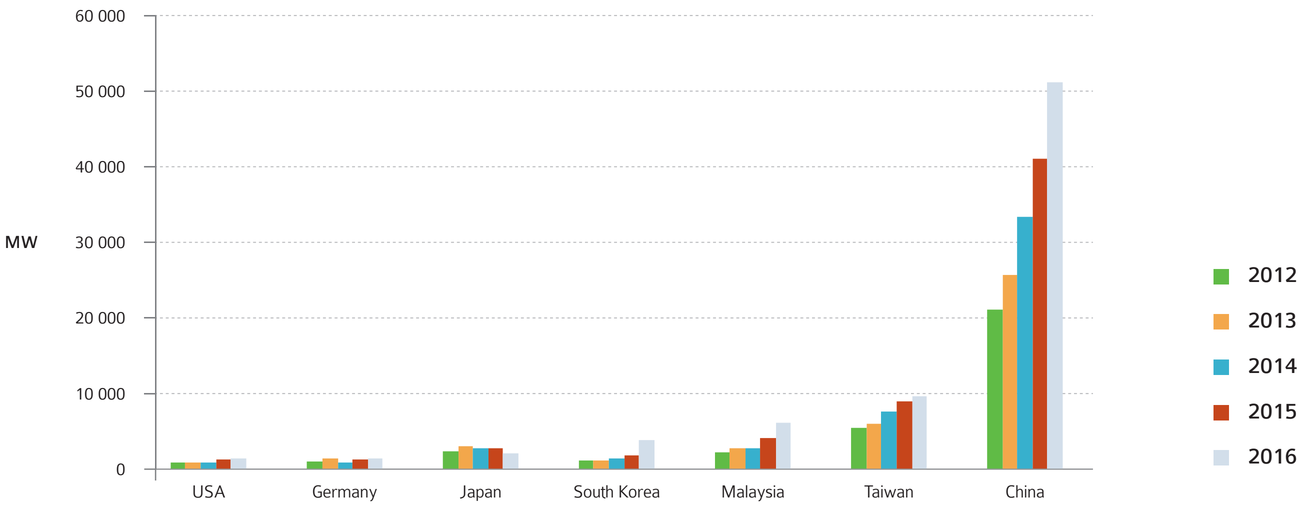
WHY PRODUCTION VOLUME DOES NOT MATCH INSTALLED CAPACITY

IEA PVPS tracked down the global PV module production volume and installed capacity for years. It is reasonable to count a certain quantity of PV modules in the distribution stock waiting for PV projects. However, if we sum up each year's production volume and compare it with global cumulative PV installations, a huge difference is observed. Outsourcing solar cells or producing GWs of PV modules by OEM or ODM contractors has been common for PV manufacturers to address increase of demand, avoid ADs and CVDs, or overcome cost pressures. In this practice, sometimes PV modules production might have been counted twice (or more). This so-called "double counting" has been recognized from the early stage of PV industry. With the growth of the PV market, differences between installed capacity and production volume expanded. It is also noted that shipment and production volume are different. This would require to dig seriously into these discrepancies since market numbers seem in line with many proxies.

FIGURE 20: PV MODULE PRODUCTION PER TECHNOLOGY IN IEA PVPS COUNTRIES 2011-2016 (MW)

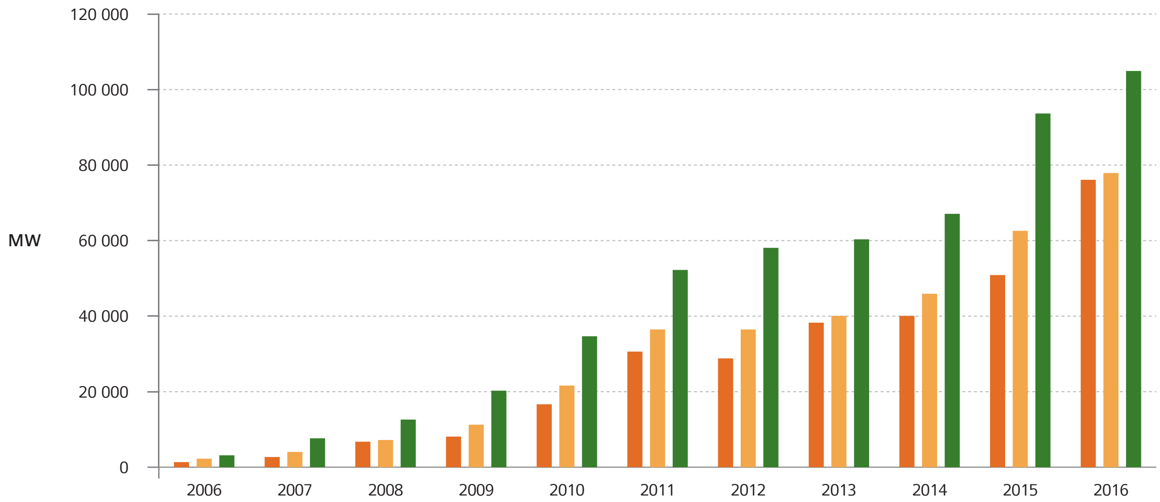
SOURCE IEA PVPS, RTS CORPORATION.

FIGURE 19: EVOLUTION OF THE PV INDUSTRY IN SELECTED COUNTRIES - PV CELL PRODUCTION (MW)



SOURCE IEA PVPS, RTS CORPORATION.

FIGURE 21: YEARLY PV INSTALLATION, PV PRODUCTION AND PRODUCTION CAPACITY 2006-2016 (MW)



SOURCE IEA PVPS, RTS CORPORATION.

TABLE 5: EVOLUTION OF ACTUAL MODULE PRODUCTION AND PRODUCTION CAPACITIES (MW)

	ACTUAL PRODUCTION			PRODUCTION CAPACITIES			
YEAR	IEA PVPS COUNTRIES	OTHER COUNTRIES	TOTAL	IEA PVPS COUNTRIES	OTHER COUNTRIES	TOTAL	UTILIZATION RATE
1993	52		52	80		80	65%
1994	0		0	0		0	0%
1995	56		56	100		100	56%
1996	0		0	0		0	0%
1997	100		100	200		200	50%
1998	126		126	250		250	50%
1999	169		169	350		350	48%
2000	238		238	400		400	60%
2001	319		319	525		525	61%
2002	482		482	750		750	64%
2003	667		667	950		950	70%
2004	1 160		1 160	1 600		1 600	73%
2005	1 532		1 532	2 500		2 500	61%
2006	2 068		2 068	2 900		2 900	71%
2007	3 778	200	3 978	7 200	500	7 700	52%
2008	6 600	450	7 050	11 700	1 000	12 700	56%
2009	10 511	750	11 261	18 300	2 000	20 300	55%
2010	19 700	1 700	21 400	31 500	3 300	34 800	61%
2011	34 000	2 600	36 600	48 000	4 000	52 000	70%
2012	33 787	2 700	36 487	53 000	5 000	58 000	63%
2013	37 399	2 470	39 868,5	55 394	5 100	60 494	66%
2014	43 799	2 166	45 964,9	61 993	5 266	67 259	68%
2015	58 304	4 360	62 664	87 574	6 100	93 674	67%
2016	73 864	4 196	78 060	97 960	6 900	104 860	74%

NOTE: CHINESE PRODUCTION AND PRODUCTION CAPACITY ARE INCLUDED SINCE 2006 EVEN THOUGH CHINA PARTICIPATES IN PVPS SINCE 2010.

SOURCE IEA PVPS & OTHERS.

DOWNSTREAM SECTOR

In the PV industry, an overview of the downstream sector can be described as in Figure 22 (example of utility scale projects).

PV developers have been active in PV power plant developments in the countries where either power purchase agreement (PPA) are guaranteed or feed-in tariff programs are implemented. While developers sell PV power plants to "independent power providers" or investors, some developers own PV power plants as their own assets. Companies providing Engineering, Procurement and Construction for PV systems (mainly utility scale application but larger commercial or industrial applications also fall in this category) are called EPCs. EPCs include pure-players companies and general construction companies offering services for installing PV systems. Integrated PV developers sometimes conduct EPC services by themselves. Some companies develop PV power plant and own them. Some companies provide EPC and own PV power plants as well until they sell PV power plants to Independent Power Producers (IPPs). Generally, utility-scale projects are owned by independent power producers (together with investors), who sell the power to utilities under a long-term PPA. Equity investors or other financial institutions also play an important role for PV project development as equity or loan providers.

Companies doing business in the downstream sector have various origins: subsidiary of utility companies, subsidiaries of PV modules or Polysilicon manufacturers, companies involved in conventional energy or oil-related energy business. In 2016, a shift to renewable energy in utility-origin or conventional energy-origin companies, namely, Engie (France), EDF (France), Total (France), Enel (Italy), RWE (Germany), E.On (Germany) and Acciona (Spain) have been increasing their presence in PV and other renewable energy sectors.

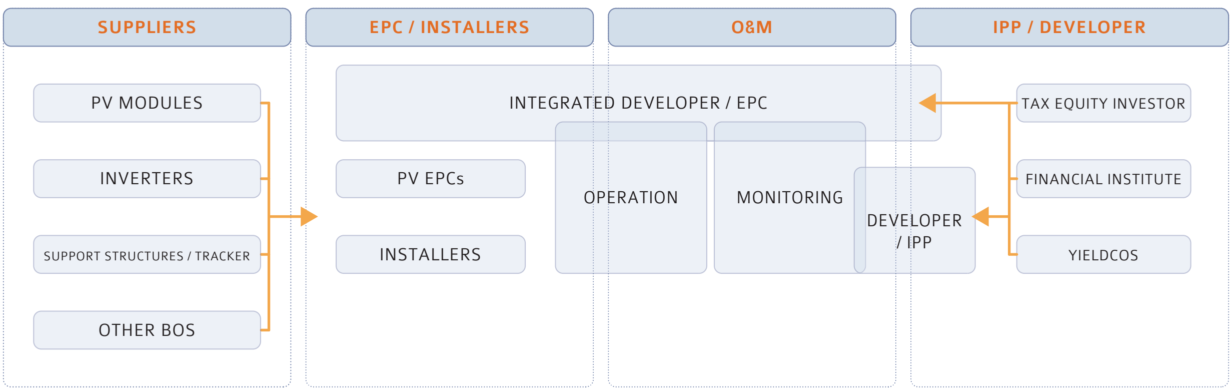
Some of these companies developed their energy storage business in 2016. E.ON announced a partnership with IBC Solar on energy storage systems. Total agreed to acquire SAFT from France. Asian utilities are also active in the renewable energy field. The Malaysian national electric power company developed utility-scale PV projects in Malaysia and participated in the tenders held in Middle East. KEPCO, the South Korean national power company is active in investing solar projects in Japan, Mongolia, the USA and more.

It is also noted that several integrated companies are present in the downstream sector. Those companies produce PV modules or polysilicon, develop PV projects, provides EPCs, O&M services. One of them is First Solar: The company announced it achieved more than 6 GW of installations with its thin-film PV modules. Crystalline silicon PV modules manufacturers such as Jinko Solar, Canadian Solar, SunPower and Hanwha Q-cells are also active in downstream sector. Notable polysilicon manufacturers investing in the international downstream business are GCL-Poly Energy in China and OCI in South Korea. GCL-Poly Energy had about 370 MW of PV power plant in USA and China as of the end of 2016. In addition, the company is a major shareholder of GCL New Energy that owns 3,52 GW of PV power plants. OCI Global, an OCI subsidiary targeted to develop a total of 650 MW of PV projects in the USA by the end of 2016 and has a plan to invest more than 1GW in PV projects in China and India by 2018.

The picture of the downstream sector for distributed generation is different from the one of utility-scale PV applications. Distributed PV systems for residential, commercial and industrial applications are owned generally by the building owner or third-party companies. In some countries, especially in the USA, third- party owned (TPO) business models are quite active. The companies in TPO business model provide PV systems to property owners and sign an agreement to provide PV power generally at a lower price than the retail electricity price. The major example of TPO companies active in the USA are Sunrun, SolarCity (Tesla), Vivint Solar, etc. These companies also provide loans to customers who want to keep the ownership of PV systems.

Companies financing or developing PV projects through crowd financing are reported. Financing options in specific countries are reported in National Survey Reports.

FIGURE 22: OVERVIEW OF DOWNSTREAM SECTOR (UTILITY PV APPLICATION)



SOURCE IEA PVPS & OTHERS.

Balance of System Component Manufacturers and Suppliers

Balance of system (BOS) components manufacturers represent an important part of the PV value chain and are accounting for an increasing part of the system costs as the PV module prices is falling. Accordingly, the production of BOS products has become an important sector of the overall PV industry.

The inverter technology has become the main focus of interest since the penetration ratio of grid-connected PV systems has increased to the extent that it represents now close to 99% of the market. New grid codes require the active contribution of PV inverters to grid management and grid protection, which implies that new inverters are now developed with sophisticated control and interactive communications features. With these functions, PV plants can actively support the grid; for instance by providing reactive power and other ancillary services.

PV inverters are produced in many IEA PVPS member countries; China, Japan, South Korea, Australia, the USA, Canada, Germany, Spain, Austria, Switzerland, Denmark, and Italy. Originally, the supply structures of PV inverters were affected by national codes and regulations so that domestic or regional manufacturers tended to dominate domestic or regional PV markets. However, lower price imported products started to increase their share in countries and segments where the cost reduction pressure is strong. In such markets, leading players with global supply chains are taking the share of regional players.

Chinese inverter manufacturers delivered more than 40 GW in 2016, a 81% growth from the previous year. It is estimated that Chinese inverters share in the global market was around 51%. Among the chinese production, 35 GW were for the domestic market and 4 GW only was exported. While in 2011 China counted only one inverter manufacturers in the top 10 (Sungrow), in 2016, 5 Chinese companies ranked into the top 10 in shipping volume (including Huawei (No.1), Sungrow (No.2)). 7 companies in China have now more than 1 GW/year of manufacturing capacity.

The products dedicated to the residential PV market have typical powers ranging from 1 kW to 10 kW, and single (Europe) or split phase (the USA and Japan) grid-connection. For larger systems, PV inverters are usually installed in a 3-phases configuration with typical sizes of 10 to 250 kW. For utility-scale applications, 2 to 3 MW centralized inverters are common. 5 MW inverters are also available. Utilization of string inverters has been increasing mainly in the Asia-Pacific region. For utility-scale projects, centralized installations of string inverters that simplifies O&M for inverters are now proposed.

Inverter technologies have improved with the adoption of new power semiconductor devices such as SiC and GaN. These devices allow higher conversion efficiencies together with a reduction in size and weight resulting in lower LCOE. Some manufacturers offer inverter and solar storage solutions for the market where self-consumption is major driver.

The module level power electronics (MLPE) market consisting of microinverters and DC optimizers (working at module level) is expanding, especially in the USA. For example, the share of MLPE reached 53% in the Californian residential market. MLPE can help achieving a higher output for PV arrays with shading and has been proven more effective to rapidly shutdown in case of fire. It is estimated that about 3 GW of those devices were shipped in 2016. It is expected that the MLPE market could grow to 10 GW from 2020 onwards.

As well as PV module suppliers, inverter manufacturers have been suffering from the cost pressure and tighter competition. The consolidation of manufacturers is still underway, and players need to differentiate their products. Some companies started to provide integrated solutions including operation and monitoring of PV power plants.

The production of specialized components, such as tracking systems, PV connectors, DC switchgear and monitoring systems, represents an important business for many large electric equipment manufacturers. With the increase of utility-scale PV power plants, the market for single-axis or double-axis trackers has been growing. It is probable that almost 60% of utility-scale PV power plants have adopted trackers.

For distributed generation, the launch of packaged products consisting of storage batteries and PV with Home Energy Management Systems (HEMS) or Building Energy Management Systems (BEMS) has been announced. Especially the focus on storage batteries is growing with the development of self-consumption business models and tighter codes for building energy efficiency. In markets that already achieved a rather high penetration of PV (California, Hawaii, Australia, etc.), the demand for storage batteries for PV system is increasing. However, such batteries are still expensive without subsidies. Utility-scale storage projects have also been reported in regions where PV penetration is increasing rapidly. the trends for storage batteries for decentralized and centralized generation in IEA PVPS countries are described below.

In the USA, California has driven the development of energy storage, as the US leading market for distributed PV. California's Self-Generation Incentive Program (SGIP) offers rebates for "advanced energy storage" that vary according to system size. Current incentives vary between 0,32 and 0,45 USD/Wh. To-date, it has funded approximately 59 MW of storage, and 280 unique storage projects. Additionally, Hawaii Electric Company has identified 17 utility-led energy storage projects to assist the integration of renewable energy. The current Hawaiian self-consumption program also provides a self-supply option, where PV owners can gain preferential permitting treatment by consuming all PV electricity on site (no value is given to exported generation). Recently, an increasing number of PV systems in Hawaii are coupled with smart water heaters, battery storage systems, and other load controls which allow to increase the self-consumption rates.

In Germany, since 2013, the public bank KfW is running a market stimulation program to boost the installation of local stationary storage systems in conjunction with small PV systems below 30 kW. The funding is two-fold: A loan and a grant on the repayment. The first phase ended in 2015 and was limited to a total of 25 MEUR of grants. A second phase started in 2016 and will last until the end of 2018 with a funding volume of 10 MEUR (grants) per year.

DOWNSTREAM SECTOR / CONTINUED

In Australia, storage batteries incentives are offered by local governments. The City of Adelaide provides 50% of the cost of batteries up to a value of 5 000 AUD, in addition to a further 5 000 AUD covering 20% of the price of a PV system. The Australian Capital Territory (ACT) government's Next Generation Storage Program paid a subsidy of 900 AUD per kW of peak output, as part of a rollout of 36 MW of distributed storage across 5 000 homes and businesses between 2016 and 2020. The Northern Territory government's Home Improvement Scheme offers a 2 000 AUD subsidy for the installation of rooftop solar and storage systems. In 2016, many electricity network operators conducted tests of batteries within their substations, and within homes. For example, Energex and Ergon trailed 80 sites across Queensland while SAPN offered highly subsidized PV-storage systems as part of a trial for 100 houses.

In Japan, storage batteries are supported in the subsidies for installations of net zero energy house (ZEH) and demonstration projects of ZEB. A project to accelerate dissemination of net zero energy house (ZEH) is funded with 1,25 million JPY per house. To introduce a storage system, 50 000 JPY are granted per kWh of storage capacity. It covers maximum one-third of the cost or 500 000 JPY. With the demonstration project for net zero energy building (NZEB)", part of the storage costs is subsidized to for renovation of existing buildings and new buildings. It introduces high-performance building materials or equipment as component of ZEB. The subsidy can cover up to two-thirds of the cost and the cap of the total subsidy is 1 BJPY/year. The Tokyo Metropolitan Government (TMG) started a project to expand the development of renewable energy for local production and local consumption. It supports private businesses which install renewable energy power generation plants for self-consumption in Tokyo. Storage batteries which are introduced together with PV systems are also eligible for the subsidy. The subsidy rate is one-third or less of the eligible cost for SMEs with the cap of 50 MJPY and one-sixth or less of the eligible cost for other companies with a cap of 25 MJPY. The Ministry of Economy and Industry (METI) also promotes the development of electricity storage technology using large-capacity storage batteries. To adjust short-cycle variations and balance supply and demand following the large-scale introduction of renewable energy, electric power companies conducts projects to introduce large-capacity storage batteries in substations with the support from METI.

The Korean government is conducting technological development through smart-grid projects. MOTIE launched the smart grid test-bed project in September 2012 in Jeju island and invested 76,6 billion KRW (a total of 249,5 billion KRW including the 172,9 billion KRW investment from the private sector). The project ended in May 2013, and it aimed at verifying the energy systems integration technology using smart metering devices. The project also aimed at developing business models for commercialization. The 2nd phase of the smart grid diffusion project was designed in 2014 and expected to be launched in 2016. The utilization of energy storage systems are also reported for rural electrification. The "Energy-independent Islands" project was jointly planned by the central government and the Gyeongbuk provincial government in 2014 and was launched in 2015 for Ulleungdo island, and will be expanded to more islands in Korea. Wind power, PV, geothermal and Energy Storage System (ESS) will be combined to increase the new and renewable energy share in Ulleungdo island from 3.6% in 2014 to 68% in 2017. 30 MWh ESS will be installed by 2017.

TRADE CONFLICTS

Trade conflicts concerning PV products, including polysilicon, continued to impact business strategies of PV companies. To avoid the duties imposed in several countries for different kinds of products, PV module manufacturers announced new production enhancement plans in Malaysia, Thailand, India, and some European countries. In this section, the trends regarding the major trade conflicts observed in 2016 are described.

The US Department of Commerce (DOC) revised the margins for anti-dumping duties (ADs) and countervailing duties (CVDs) in 2016. Compared to ADs and CVDs for Chinese PV products and ADs for Taiwanese products decided in 2013 and revised in January 2015, reviewed AD and CVD margins are lower for most of companies. Chinese manufacturers adapted to use solar cells made in China instead of solar cells made-in Taiwan. In 2017, DOC revised ADs and CVDs related to made in Taiwan crystalline Silicon PV cells and modules. The duties for ADs for the companies cooperating to the review process remained at a lower level, below 4,2%. Since the revised levels are lower for most companies, it seems that the revision has not produced any significant impact on the price level.

A new issue emerged in the USA in 2017. Suniva, a bankrupt US PV cells and modules manufacturer filed a petition to the International Trade Commission (ITC) under DOC together with SolarWorld America. They claimed that some serious damages have been caused by imported solar cells and modules. ITC started a survey in May 2017 and concluded that imported crystalline Silicon PV products caused a damage to domestic PV manufacturers. If the safeguard measure will be implemented, all the imported PV cells and modules may be subject to specific measures such as setting a minimum imported price. The final decision of ITC on such concrete measures remains to be seen at the time of writing these lines. But in case ITC implements a Minimum Imported Price, PV modules prices are expected to rise in the USA and according to some stakeholders could result in a possible decrease of utility scale PV projects.

In Europe, The European Commission (EC) and the Chinese PV industry continued to implement an agreement on minimum imported price (MIP) and a maximum shipping volume. PV products are subjects to ADs and CVDs if producers do not participate in the agreement. In February 2017, the EC decided to extend the agreement for 18 months and announced that duty margins and MIP would be gradually decreased following cost reduction trends of PV products. In February 2016, EC announced to apply ADs and CVDs to Chinese PV modules imported via Taiwan and Malaysia. Several major PV modules producers voluntary decided to withdraw from the agreement because the MIP did not reflect the actual market prices trends. Most of these manufacturers established their production facilities outside of China. In July, DG Trade announced a draft proposal to set the MIP level quarterly. Because of the withdrawal of major Chinese companies (which prefer to pay the duties), the effectiveness of the MIP agreement has been questioned.

In Australia, the Anti-dumping Committee concluded its antidumping investigation started in May 2014. While the Committee confirmed dumping in April 2015, it did not impose duties because damage to Australian industry was not observed. In 2016, the Committee reviewed the survey results and concluded that influence on the domestic industry was minor while dumping was recognized.

The Turkish government decided to impose ADs for Chinese PV modules in April 2017. The committee responsible for the survey decided 27% of dumping margin.

In July 2017, the Indian Directorate General of Anti-Dumping and Allied Duties (DGAD) under the Department of Commerce initiated an antidumping survey following a petition submitted by the Indian Solar Manufacturers Association (ISMA). The subject of the survey are PV cells and modules produced in China, Malaysia and Taiwan. While it is expected that the survey takes a year or more, preliminary results will be announced earlier. In August 2017, the Ministry of Finance decided to impose a duty on glass for PV modules coming from China. In parallel the Indian government agreed to terminate the Domestic Contents Requirement (DCR) in its national tender programs by the 14th of December 2017 following a conclusion of the World Trade Organization (WTO) that concluded that DCR is violating the global trading agreement.

In 2016, China decided an 18 months extension of ADs and CVDs on polysilicon made in USA and Europe and ADs on Korean-made polysilicon set in May 2014. Mainly US manufacturers are affected by ADs and CVDs while Korean producers can continue to import it with lower ADs. The Chinese Ministry of Commerce decided to review duty margins for polysilicon made in South Korea in November 2016. Wacker Chemie, a Germany polysilicon producer avoids AD by the agreement on the price with the Chinese government. REC Silicon of Norway that possesses manufacturing plants in the USA announced to establish a joint venture with Chinese companies to construct a plant using the FBR process in China.

PV CONTRIBUTION TO ELECTRICITY DEMAND

1,6 %
Share of PV in the global electricitiy demand in 2016

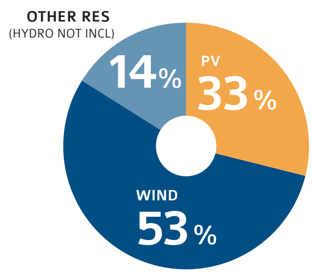
TOP 5 PV MARKET IN 2016

CHINA	34,6 GW
USA	14,8 GW
JAPAN	7,9 GW
INDIA	4,0 GW
UK	2,2 GW

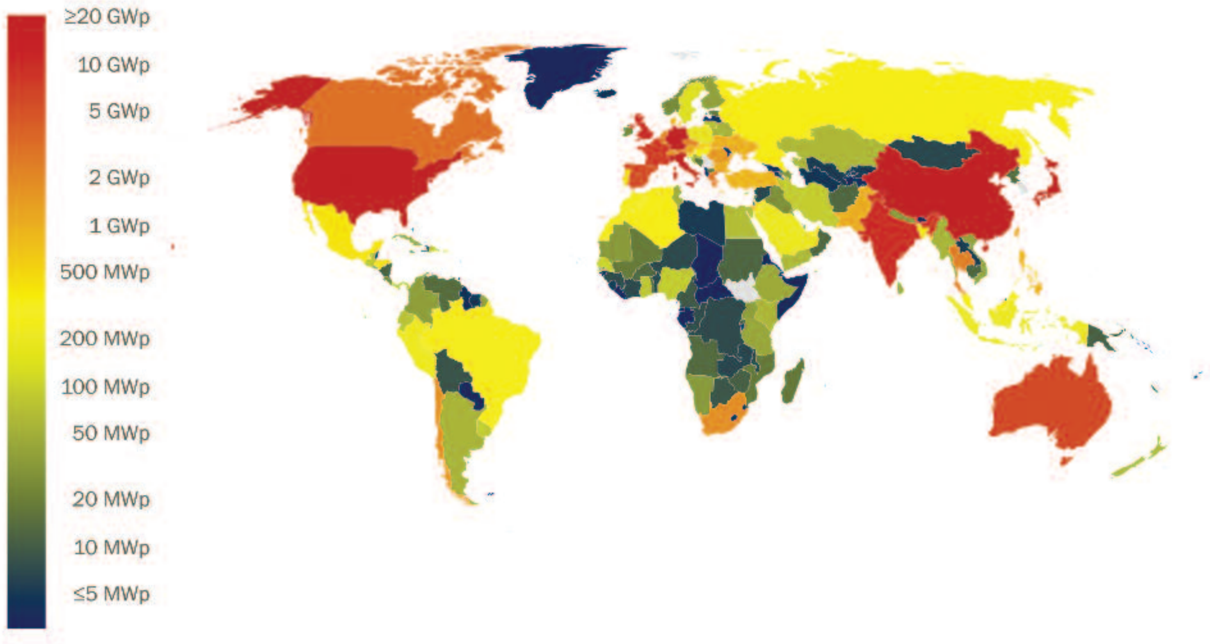
26 COUNTRIES HAD AT LEAST **1 GW** IN 2016

13 COUNTRIES INSTALLED AT LEAST **500 MW** EACH

SHARE OF PV IN THE TOTAL RES INSTALLED CAPACITY IN 2016



GLOBAL CUMULATIVE PHOTOVOLTAIC SOLAR POWER BY THE END OF 2016



SOURCE CH. WERNER, A. GERLACH, CH. BREYER, G. MASSON. 2017. GROWTH REGIONS IN PHOTOVOLTAICS 2016 UPDATE ON LATEST GLOBAL SOLAR MARKET DEVELOPMENT

THE MOST COMPETITIVE TENDERS IN THE WORLD UNTIL Q4 2017 // USD/MWh

MEXICO	20,6
CHILE	21,5
PORTUGAL	38,8
GERMANY	38,8
SPAIN	38,8
INDIA	48
FRANCE	50,2

303 GW
global PV capacity
end of 2016

76 GW
commissioned in 2016

five

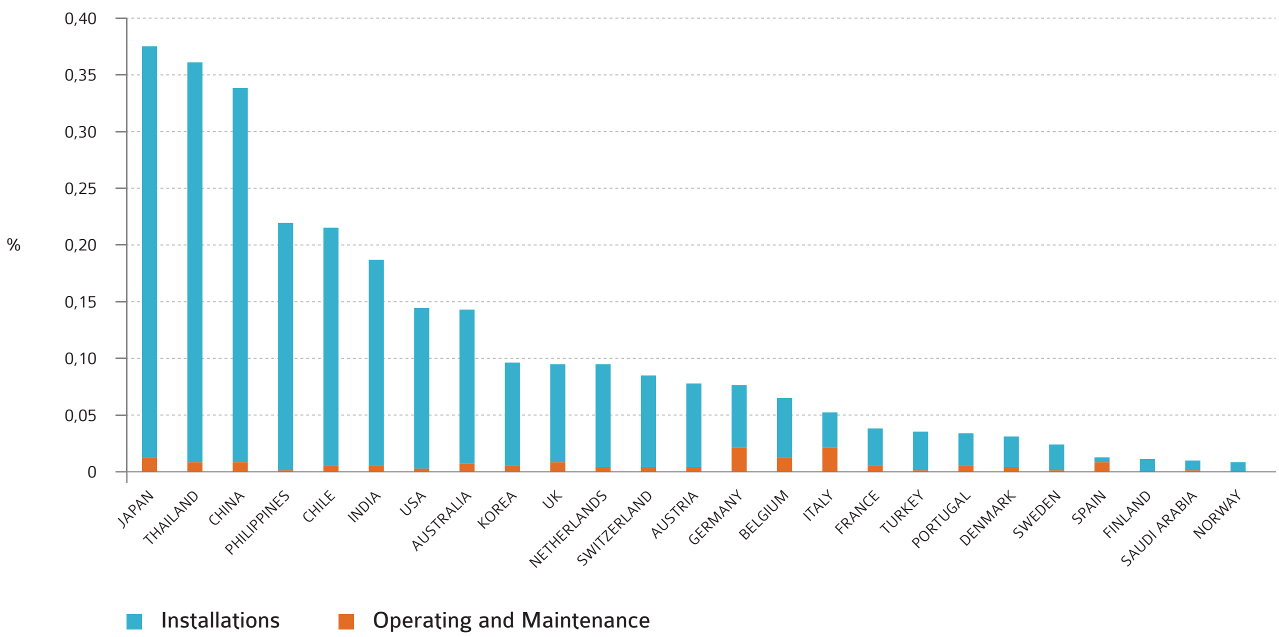
PV AND THE ECONOMY

VALUE FOR THE ECONOMY

The 50% growth of the PV installations between 2015 and 2016 and decline in prices, especially for utility-scale plants caused the business value of PV to grow by 30% at approximately 110 BUSD.

Figure 23 shows the estimated business value for PV compared to GDP in IEA PVPS reporting countries and other major markets. The value corresponds to the internal PV market in these countries, without taking imports and exports into account. For countries outside the IEA PVPS network or countries that did not report a specific business value, this is estimated based on the average PV system price.

FIGURE 23: BUSINESS VALUE OF THE PV MARKET COMPARED TO GDP IN % IN 2016



SOURCE IEA PVPS & OTHERS.

VALUE FOR THE ECONOMY / CONTINUED

Some countries have benefited from exports that have increased the business value they obtained through the PV market while huge imports in other countries have had the opposite effect. Some countries could still be seen as net exporters, creating additional value next to their home PV market.

O&M

The turnover linked to Operation and Maintenance is not considered in detail, given the variety of existing maintenance contracts and costs. Although, one might estimate the global turnover related to O&M in the PV sector between 5 and 20 BUSD per year depending on assumptions. In the figure above, the O&M contribution to the business value has been estimated based on the lowest assumptions.

CONTRIBUTION TO THE GDP

The business value of PV market should be compared to the GDP of each country. In 2016, the business value of PV represented less than 0,4% in all countries considered, as can be noticed in Figure 23. The PV business value in Japan in 2016 represented 0,36% of the country GDP, down from the 0,50% in 2015 and the 0,56% in 2014, up from 0,23% in 2013. Japan is then followed by two booming PV markets last year, Thailand and China, for which the PV business covered in 2016 were 0,35% and 0,36% of their GDP respectively. The business value of the industry is in general more complex to assess, due to decentralized production and transnational companies. In that respect it is not considered here.

Figure 24 shows how the PV market and the GDP are correlated. The first PV markets to develop, especially in Europe, had a rather high GDP/capita. The highest PV penetrations are therefore concentrated in countries with a high GDP/capita. The new markets where PV is developing have a lower GDP/capita, which illustrate the paradigm change actually ongoing: PV develops now in countries where PV electricity is competitive and needed, rather than in countries that had money to ensure its development. This trend will continue to develop, with more emerging countries joining the PV market.

TRENDS IN EMPLOYMENT

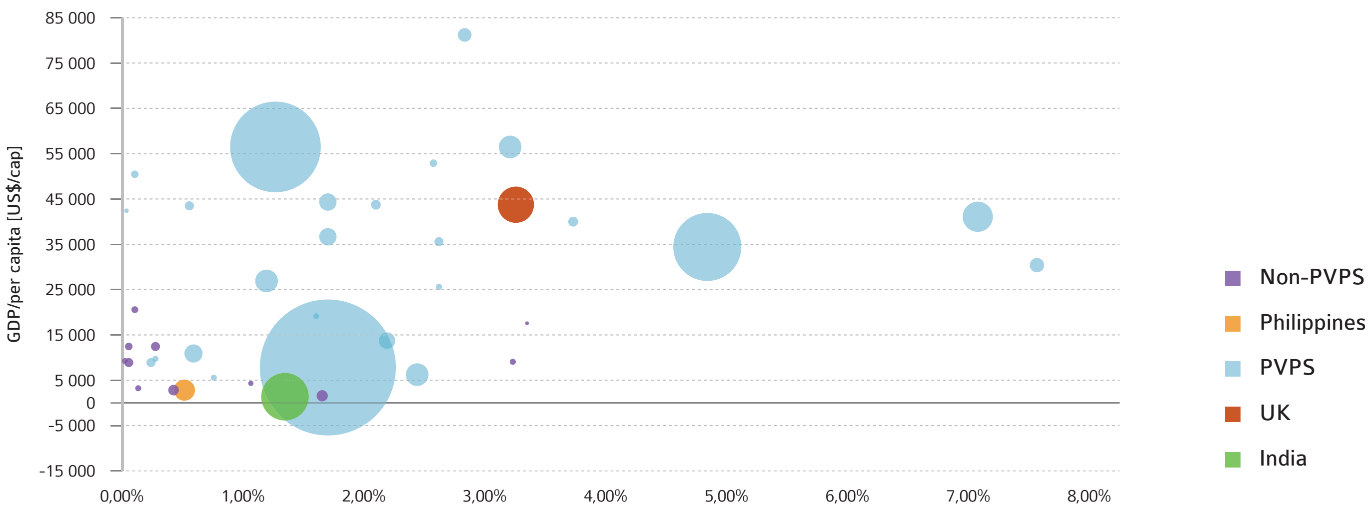
Employment in the PV sector should be considered in various fields of activity: research and development, manufacturing including equipment, but also deployment, maintenance and education. However these jobs are significantly diverse.

PV labour places are evolving rapidly in several countries due to the changes in the PV markets and industry. The decrease of the market in several key European countries has quickly pushed the installation jobs down while some other countries, where the market was growing, experiencing an opposite trend, especially in Asia and America.

Development and industrial jobs went up again in 2016 where manufacturing and installations increased. The development of PV manufacturing in new locations should push some further development in jobs creation.

In general, the evolution of employment is linked to the industry and market development, with important differences from one country to another due to local specifics. It remains difficult to estimate the number of jobs created by the development of PV since a part of them stands in the upstream and downstream sectors of the value chain, mixed with others. The National Survey Reports detail jobs in most countries participating to the IEA PVPS program.

FIGURE 24: PV PENETRATION 2016 AND GDP PER CAPITA



SOURCE IEA PVPS & OTHERS.

six

COMPETITIVENESS OF PV ELECTRICITY IN 2016

The fast price decline that PV experienced in the last years has already opened possibilities to develop PV systems in many locations with limited or no financial incentives. However, the road to full competitiveness of PV systems with conventional electricity sources depends on answering many questions and bringing innovative solutions to emerging challenges.

This section aims at defining where PV stands with regard to its own competitiveness, starting with a survey of system prices in several IEA PVPS reporting countries. Given the number of parameters involved in competitiveness simulations, this chapter will mostly highlight the comparative situation in key countries. Prices are often averages and should always be looked at as segment-related.

SYSTEM PRICES

Reported prices for PV systems vary widely 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.

Figure 25 shows the range of system prices in the global PV market in 2016. It shows that half of the PV market consists in prices below 1,1 USD/Wp. While this figure is based on reported prices and some averages it explains the rationale behind low cost PV installations in the utility-scale segment. The second half of the market mixes more costly utility-scale PV together with distributed PV applications by nature costlier.

On average, system prices for the lowest priced off-grid applications are significantly higher than for the lowest priced grid-connected applications. This is attributed to the fact that off-grid systems might require storage batteries and associated equipment. Large-scale off-grid systems are often installed in places far from the grid but also far from places easily accessible. The higher price asked for such installations also depends on higher costs for transport of components, technicians, without even mentioning the higher cost of maintenance.

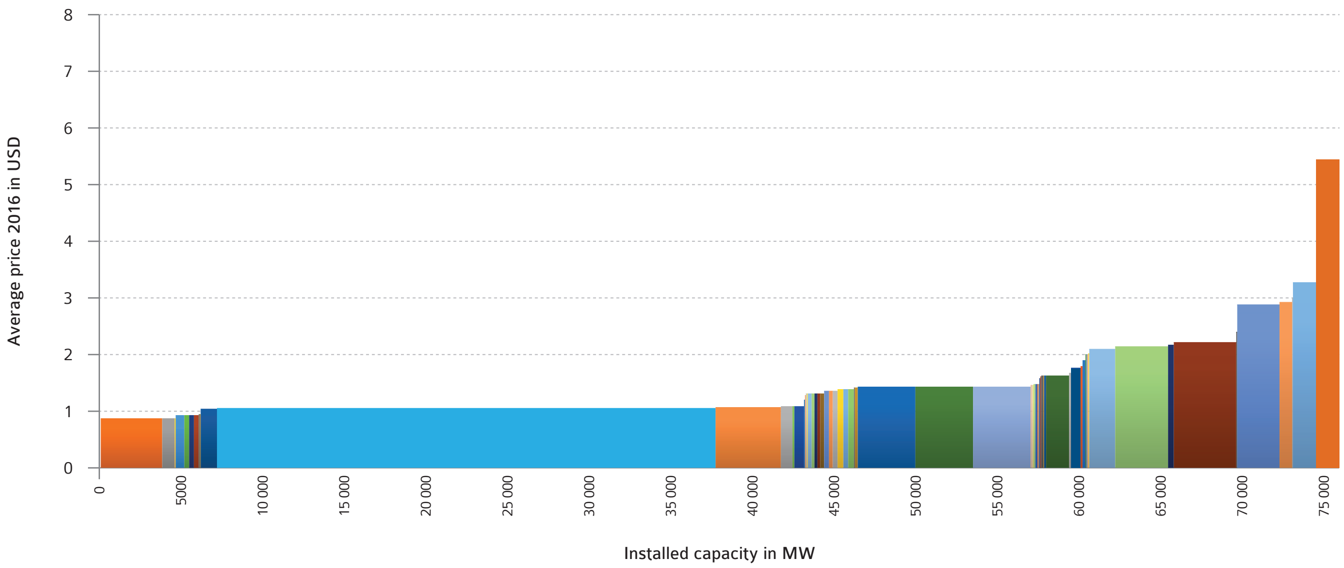
Additional information about the systems and prices reported for most countries can be found in the various national survey reports; excluding VAT and sales taxes. More expensive grid-connected system prices are often associated with roof integrated slates, tiles, one-off building integrated designs or single projects: BIPV systems in general are considered more expensive when using dedicated components, even if prices are also showing some decline.

In 2016, the lowest system prices in the off-grid sector, irrespective of the type of application, typically ranged from about 2.71 USD/W to 12 USD/W. The large range of reported prices in Table 6 is a function of country and project specific factors. In general, the price range decreased from the previous year.

The lowest achievable installed price of grid-connected systems in 2016 also varied between countries as shown in Table 6. The average price of these systems is tied to the segment. 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 considered as quite significant factors. In summary, system prices continued to go

SYSTEM PRICES / CONTINUED

FIGURE 25: 2016 PV MARKET COSTS RANGES



SOURCE IEA PVPS & OTHERS.

down in 2016, through a decrease in module prices, balance of system, soft costs and margins, but the highest prices went down faster than the lowest ones, again. However, system prices significantly below 1 USD/Wp for large-scale PV systems are now common in very competitive tenders. The range of prices tends to converge, with the lowest prices decreasing at a reduced rate while the highest prices are reducing faster. However, local labour costs have a strong influence on final system prices with differences observed that could reach at least 0,1 USD/Wp and more. Prices for small rooftops, especially in the residential segment continued to decline in 2016 in several countries. However, higher prices are still observed depending on the market. For instance, the prices in the USA and Japan continued to be higher than for the same type of rooftop installation in Germany, even if they declined substantially in 2016.

TABLE 6: INDICATIVE INSTALLED SYSTEM PRICES IN CERTIAN IEA PVPS REPORTING COUNTRIES IN 2016

	OFF-GRID (LOCAL CURRENCY OR USD PER W)				GRID-CONNECTED (LOCAL CURRENCY OR USD PER W)							
	<1 kW		>1 kW		RESIDENTIAL		COMMERCIAL		INDUSTRIAL		GROUND-MOUNTED	
COUNTRY	LOCAL CURRENCY/W	USD/W	LOCAL CURRENCY/W	USD/W	LOCAL CURRENCY/W	USD/W	LOCAL CURRENCY/W	USD/W	LOCAL CURRENCY/W	USD/W	LOCAL CURRENCY/W	USD/W
AUSTRALIA	5,5 - 11	4,08 - 8,17	5,5 - 11,0	4,08 - 8,17	2,42	1,80	1,79	1,33	1,82	1,35	2,76	2,05
AUSTRIA	5,00	5,50	5,00	5,50	1,65	1,80	1,39	1,40	NA	-	NA	-
BELGIUM	NA	-	NA	-	1,5 - 1,9	1,66 - 2,11	1,2 - 1,5	1,33 - 1,66	1,20 - 1,40	1,33 - 1,55	NA	-
CANADA	NA	-	NA	-	3,00 - 3,5	2,26 - 2,64	2,5 - 3,00	1,88 - 2,26	2,00 - 2,5	1,5 - 1,88	2,00	1,51
CHINA	22,00	3,31	18,00	2,71	7 - 10	1,053 - 1,5	7 - 8	1,05 - 1,20	7 - 7,5	1,05 - 1,12	7 - 7,2	1,05 - 1,08
DENMARK	10,0 - 25,0	1,4 - 3,71	20,0 - 35,0	3,0 - 5,19	8 - 15,0	1,18 - 2,2	6,0 - 13,0	0,891 - 1,9	6,0 - 14,0	0,891 - 2,0	4,0 - 7,0	0,59 - 1,3
FINLAND	5,00	5,53	3,50	3,87	1,3 - 2	1,47 - 2,2	1,05 - 1,35	1,16 - 1,49	0,95 - 1,3	1,05 - 1,43	1 - 1,2	1,1 - 1,32
FRANCE	NA	-	NA	-	2,2 - 2,9	2,4 - 3,2	1,20	1,33	1,20	1,32	0,90 - 1,10	0,99 - 1,21
GERMANY	NA	-	NA	-	1,3 - 1,7	1,43 - 1,88	1,0 - 1,7	1,1 - 1,88	NA	NA	0,60	0,66
ITALY	NA	-	NA	-	1,34-1,73	1,43 - 1,88	1,20-1,48	1,326-1,635	1,08-1,26	1,19 - 1,39	0,76-0,98	1,10 -1,08
JAPAN	NA	-	NA	-	324,00	2,98	245,00	2,25	245,00	2,25	236,00	2,17
KOREA	NA	-	NA	-	1 500 - 2 000	1,29 - 1,72	2 200 - 2 300	1,89 - 1,98	NA	NA	NA	-
MALAYSIA	NA	-	NA	-	7,83	1,89	7,10	1,71	6,94	1,67	NA	-
NORWAY	30 - 150	3,57 - 17,85	45 - 150	5,35 - 17,84	15,00	2,23	14,00	1,67	12,00	1,43	NA	-
PORTUGAL	3,00	3,32	2,70	2,99	2,20	2,43	1,40	1,55	1,00	1,11	0,7 - 0,8	0,78 - 0,89
SPAIN	2,5 - 3	2,7 - 3,3	2 - 2,8	2,2 - 3,09	1,4 - 1,5	1,54 - 1,65	0,8 - 1,2	0,88 - 1,33	0,8 - 1,2	0,88 - 1,32	0,70	0,77
SWEDEN	25,00	2,92	20,40	2,38	15,00	1,75	12,30	1,44	11,60	1,35	9,20	1,07
SWITZERLAND	5,0 - 12,0	5,07 - 12,17	4,0 - 12,0	4,05 - 12,17	2,5 - 3,5	2,53 - 3,55	1,5 - 2,5	1,52 - 2,53	1,25 - 1,70	1,26 - 1,72	NA	-
USA	NA	-	NA	-	2,93	2,93	2,13	2,13	2,03	2,03	1,49	1,49

NOTE: DATA REPORTED IN THIS TABLE DO NOT INCLUDE VAT.

SOURCE IEA PVPS.

On average, the price of PV modules in 2016 (shown in Table 7) accounted for approximately between 40% and 50% of the lowest achievable prices that have been reported for grid-connected systems. In 2016, the lowest price of modules in the reporting countries was about 0,3 USD/W. It is assumed that such prices are valid for high volumes and late delivery (not for installations in 2016 or 2017). However, module prices for utility-scale plants have been reported below the average values, down to less than 0,4 USD/Wp at the end of 2016. From Q2 of 2016 prices went down significantly and reached a bottom value at the end of year. Pushed by overcapacities and lower market expectations than the capacity increases, prices for modules remained low at the beginning of 2017. It is also clear that such prices can be considered below the average production costs of many companies. Looking in depth of the revenues of some manufacturers among the most competitive, it appears that average sales are above these low prices. It can also be assumed that such prices are obtained with new production lines which production costs is significantly lower than previously existing ones.

TABLE 7: INDICATIVE MODULE PRICES (NATIONAL CURRENCY/WATT AND USD/WATT) IN SELECTED REPORTING COUNTRIES

COUNTRY	CURRENCY	LOCAL CURRENCY/W	USD/W
AUSTRALIA	AUD	0,54 - 0,8	0,4 - 0,6
AUSTRIA	EUR	0,46 - 0,7	0,5 - 0,8
CANADA	CAD	0,66 - 0,78	0,5 - 0,6
CHINA	CNY	3,1	0,5
DENMARK	DKK	2 - 6	0,3 - 0,9
FINLAND	EUR	0,5 - 0,65	0,6 - 0,7
GERMANY	EUR	0,41 - 0,57	0,5 - 0,6
ITALY	EUR	0,4 - 0,65	0,4 - 0,7
JAPAN	JPY	189	1,74
KOREA	KRW	374 - 565	0,3 - 0,5
MALAYSIA	MYR	2,33 - 3,62	0,6 - 0,9
PORTUGAL	EUR	0,5 - 0,6	0,6 - 0,7
SPAIN	EUR	0,5 - 1,05	0,6 - 1,2
SWEDEN	SEK	6,5 - 6,5	0,8 - 0,8
SWITZERLAND	CHF	0,5 - 0,8	0,5 - 0,8
USA	USD	0,37 - 1	0,37 - 1

NOTES: DATA REPORTED IN THIS TABLE DO NOT INCLUDE VAT.
GREEN = LOWEST PRICE. RED = HIGHEST PRICE.

SOURCE IEA PVPS.

SYSTEM PRICES / CONTINUED

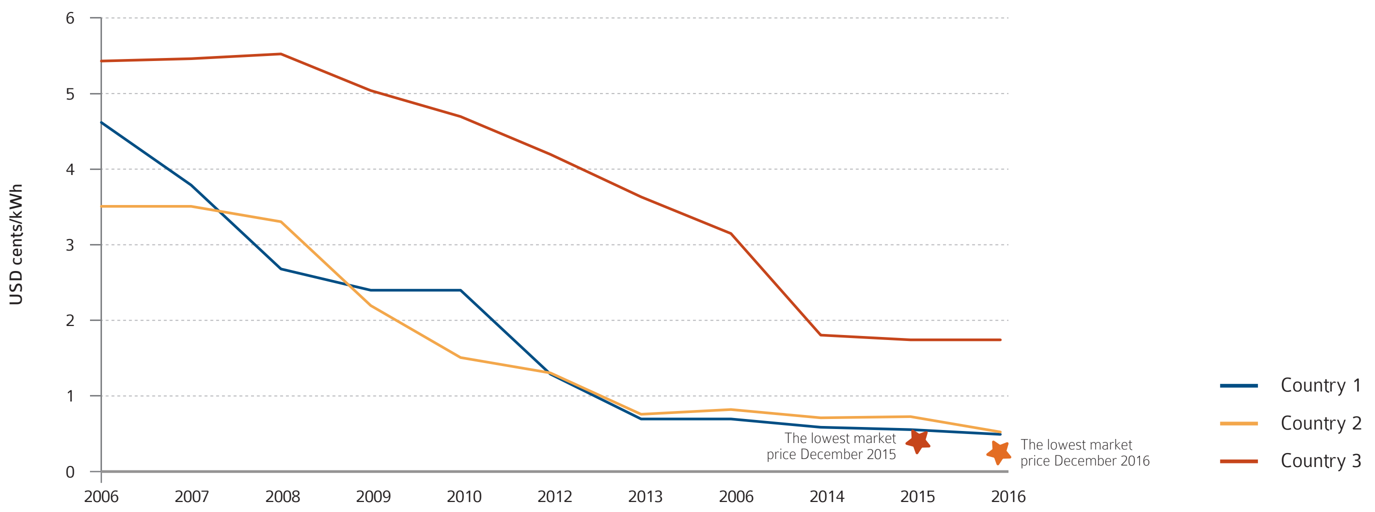
The production costs for modules continued to decline as well, with several tier 1 module manufacturers reporting at the end of 2016 production costs around 0,3 USD/Wp and declining, with some possibilities to beat the 0,3 USD/Wp threshold by the end of 2017 and going to 0,25 USD/Wp before 2020. The announcement from First Solar in 2017 to change its production lines for its new products also aims at reducing significantly its production costs that some sees close to 0,2 USD/Wp in 2019.

After having experienced prices so low that many companies lost money in 2012 and 2013, PV modules prices decreased slightly in 2014 and again in 2015. 2016 saw a restart of the price decline.

Figure 27 shows the evolution of prices for PV modules in selected key markets. Figure 25 shows the trends in actual prices of modules and systems in selected key markets. It shows that, like the modules, system prices continued to go down, at a rapid pace. Such evolution happened in all segments.

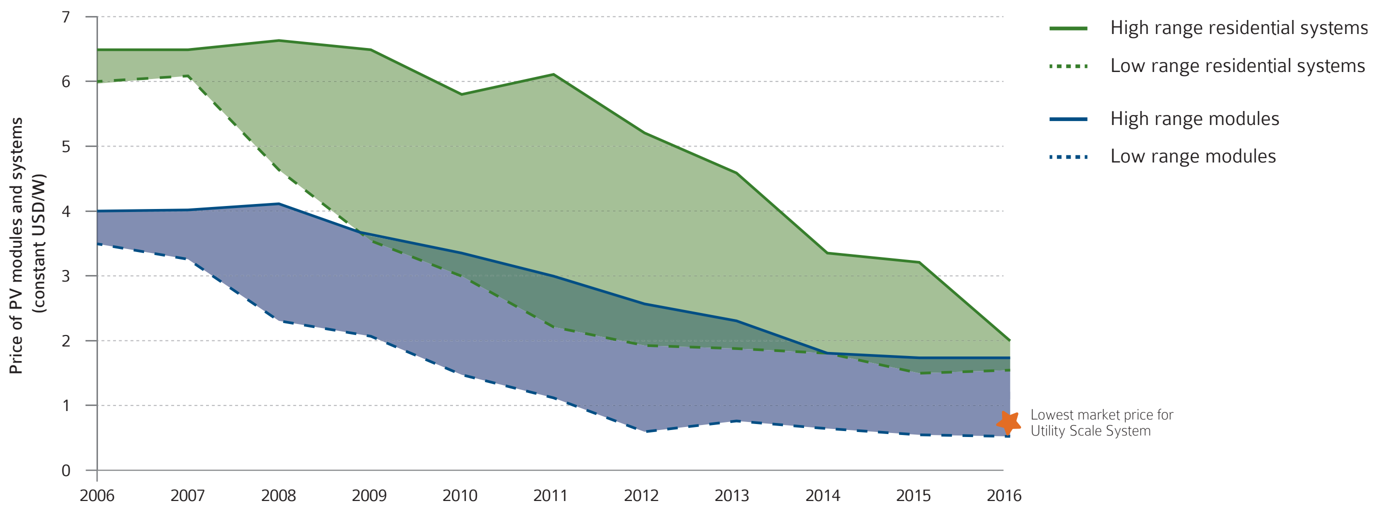
System prices for residential PV systems reveal huge discrepancies from one country to another. In particular the final price of modules as seen above but also the other price components, such as the inverter, the rest of the BoS and the installation costs. The following figures illustrate such differences which in general might be explained by the local regulations, the size of the market and the market segmentation which can be diverse.

FIGURE 26: EVOLUTION OF PV MODULES PRICES IN 3 INDICATIVE COUNTRIES IN USD CENTS/KWh



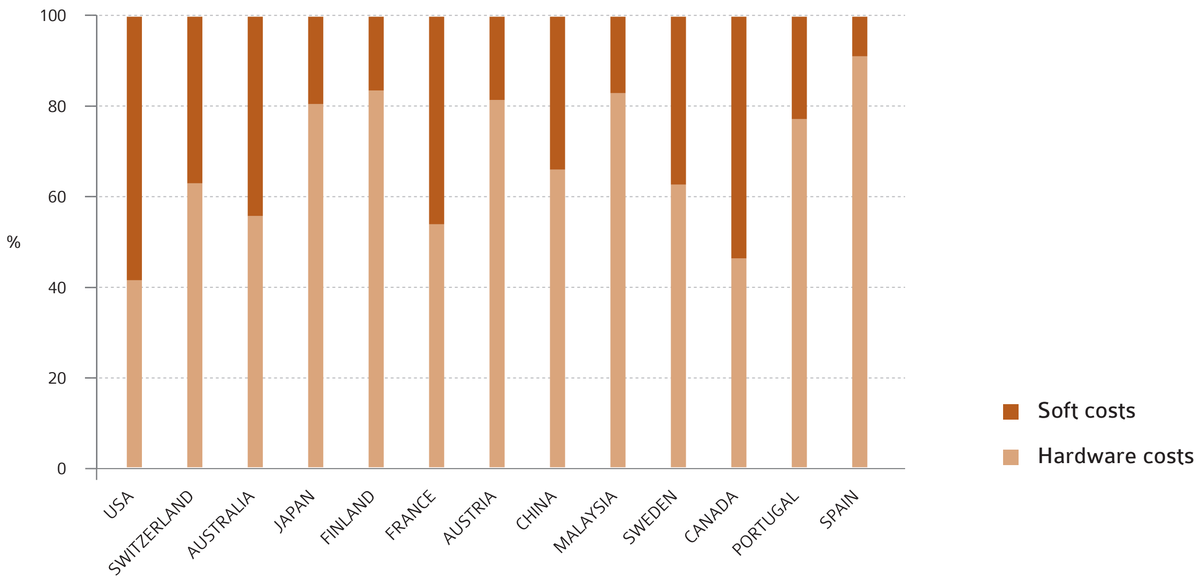
SOURCE IEA PVPS & OTHERS.

FIGURE 27: EVOLUTION OF PV MODULES AND SMALL-SCALE SYSTEMS PRICES IN SELECTED REPORTING COUNTRIES 2006 - 2016 USD/W



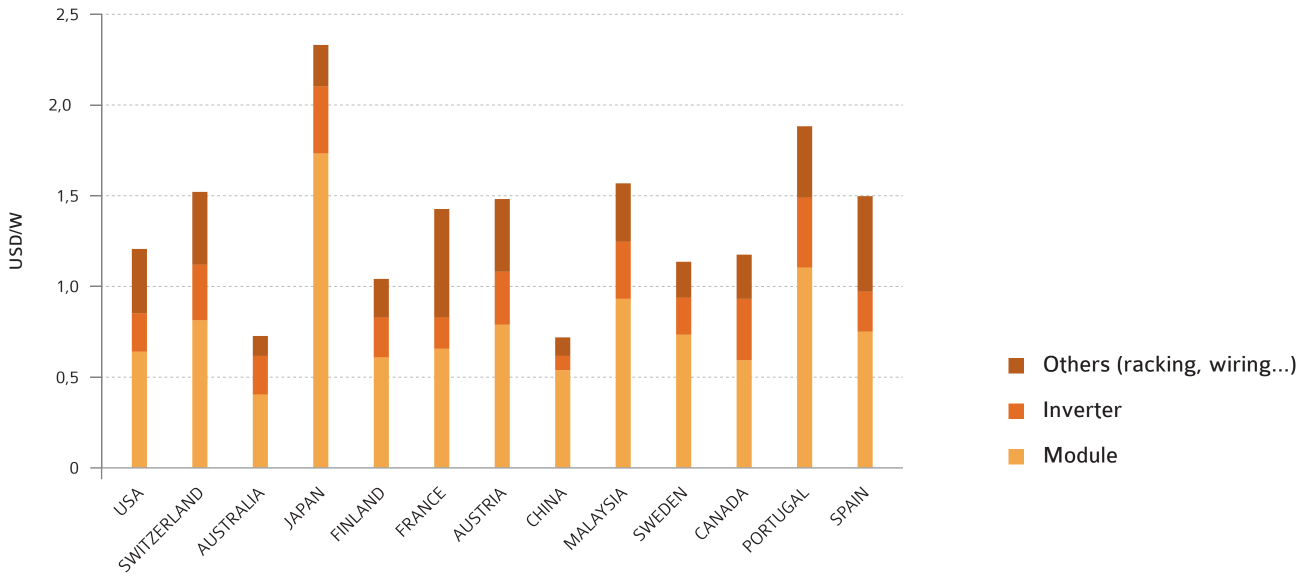
SOURCE IEA PVPS & OTHERS.

FIGURE 28: AVERAGE COST BREAKDOWN FOR A RESIDENTIAL PV SYSTEM < 10KW



SOURCE IEA PVPS.

FIGURE 29: RESIDENTIAL SYSTEM HARDWARE COST BREAKDOWN



SOURCE IEA PVPS.

SYSTEM PRICES / CONTINUED

COST OF PV ELECTRICITY

In order to compete in the electricity sector, PV technologies need to provide electricity at a cost equal to or below the cost of other technologies. Obviously, power generation technologies are providing electricity at different costs, depending on their nature, the cost of fuel, the cost of maintenance and the number of operating hours during which they are delivering electricity.

The competitiveness of PV can be defined simply as the moment when, in a given situation, PV can produce electricity at a cheaper price than other sources of electricity that could have delivered electricity at the same time. Therefore, the competitiveness of a PV system is linked to the location, the technology, the cost of capital, and the cost of the PV system itself that highly depends on the nature of the installation and its size. However, it will also depend on the environment in which the system will operate. Off-grid applications in competition with diesel-based generation will not be competitive at the same moment as a large utility-scale PV installation competing with the wholesale prices on electricity markets. The competitiveness of PV is connected to the type of PV system and its environment.

GRID PARITY – SOCKET PARITY

Grid Parity (or *Socket Parity*) refers to the moment when PV can produce electricity (the Levelized Cost Of Electricity or LCOE) at a price below the price of electricity consumed from the grid. While this is valid for pure-players (the so-called "grid price" refers to the price of electricity on the market), this is based on two assumptions for prosumers (producers who are also consumers of electricity):

- That 100% of PV electricity can be consumed locally (either in real time or through some compensation scheme such as net-metering);
- That all the components of the retail price of electricity can be compensated when it has been produced by PV and locally consumed.

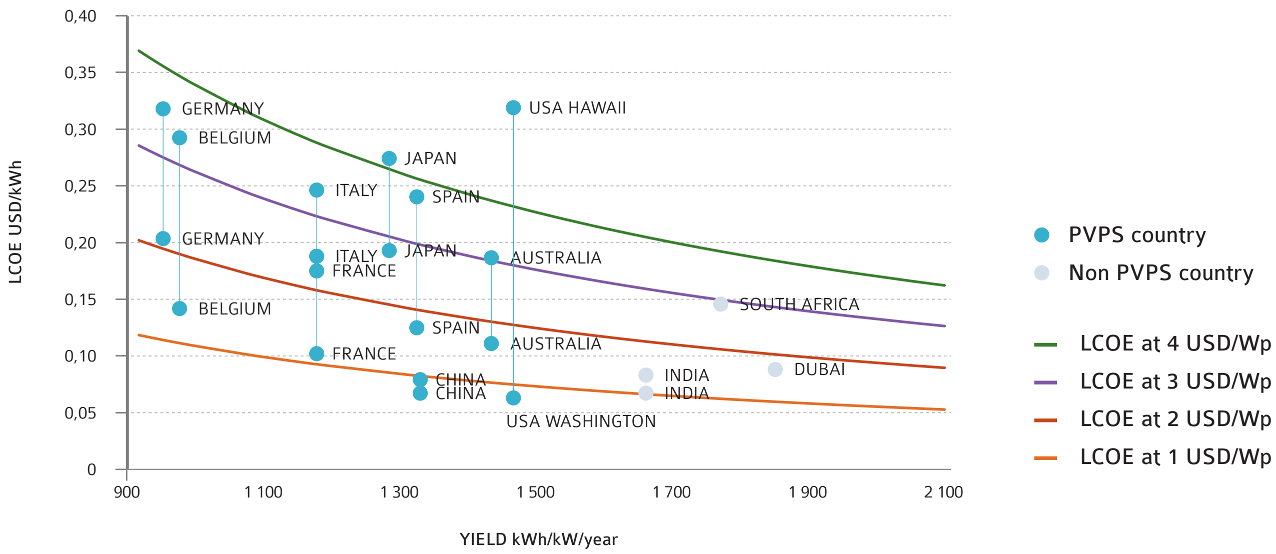
However, it is assumed that the level of self-consumption that can be achieved with a system that provides on a yearly basis up to the same amount of electricity as the local annual electricity consumption, varies between less than 30% (residential applications) and 100% (for some industrial applications) depending on the country and the location.

Technical solutions will allow for increases in the self-consumption level (demand-side management including EV charging or direct use to warm-up water, local electricity storage, reduction of the PV system size, etc.).

If only a part of the electricity produced can be self-consumed, then the remaining part must be injected into the grid, and should generate revenues of the same order as any production of electricity. Today this is often guaranteed for small size installations by the possibility of receiving a FiT for the injected electricity. Nevertheless, if we consider how PV could become competitive, this will imply defining a way to price this electricity so that smaller producers will receive fair revenues.

The second assumption implies that the full retail price of electricity could be compensated. The price paid by electricity consumers is composed in general of four main components:

FIGURE 30: LCOE OF PV ELECTRICITY AS A FUNCTION OF SOLAR IRRADIANCE & RETAIL PRICES IN KEY MARKETS*



*NOTE THE COUNTRY YIELD (SOLAR IRRADIANCE) HERE SHOWN MUST BE CONSIDERED AN AVERAGE.

SOURCE IEA PVPS & OTHERS.

COMMENTS ON GRID PARITY AND COMPETITIVENESS

- The procurement price of electricity on electricity markets plus the margins of the reseller;
- Grid costs and fees, partially linked to the consumption partially fixed;
- Taxes;
- Levies (used among other things to finance the FiT for renewables);

If the electricity procurement price can be obviously compensated, the two other components require considering the system impact of such a measure; with tax loss on one side and the lack of financing of distribution and transmission grids on the other. While the debate on taxes can be simple, since PV installations are generating taxes as well, the one on grid financing is more complex. Even if self-consumed electricity could be fully compensated, alternative ways to finance the grid should be considered given the loss of revenues for grid operators or a better understanding of PV positive impacts on the grid should be achieved.

COMPETITIVENESS OF PV ELECTRICITY WITH WHOLESALE ELECTRICITY PRICES

In countries with an electricity market, wholesale electricity prices at the moment when PV produces are one benchmark of PV competitiveness. These prices depend on the market organisation and the technology mix used to generate electricity. In order to be competitive with these prices, PV electricity will have to be generated at the lowest possible price. This will be achieved with large utility-scale PV installations that allow reaching the lowest system prices today with low maintenance costs and a low cost of capital. The influence of PV electricity on the market price is not yet precisely known and could represent an issue in the medium to long term. When a wholesale market doesn't exist as such, (in China for instance), the comparison point is the electricity from coal-fired power plants.

FUEL-PARITY AND OFF-GRID SYSTEMS

Off-grid systems including hybrid PV/diesel can be considered competitive when PV can provide electricity at a cheaper cost than the conventional generator. For some off-grid applications, the cost of the battery bank and the charge controller should be considered in the upfront and maintenance costs while a hybrid system will consider the cost of fuel saved by the PV system.

The point at which PV competitiveness will be reached for these hybrid systems takes into account fuel savings due to the reduction of operating hours of the generator. Fuel-parity refers to the moment in time when the installation of a PV system can be financed with fuel savings only. It is assumed that PV has reached fuel-parity, based on fuel prices, in numerous Sunbelt countries.

Other off-grid systems are often not replacing existing generation sources but providing electricity in places with no network and no or little use of diesel generators. They represent a completely new way to provide electricity to hundreds of millions of people all over the world.

RECORD LOW TENDERS IN 2016 AND 2017

With several countries having adopted tenders as a way to allocate PPAs to PV projects, the value of these PPAs achieved record low levels in 2016 and in 2017. These levels are sufficiently low to be mentioned since they approach, or in many cases beat, the price of wholesale electricity in several countries. While these tenders do not represent the majority of PV projects, they have shown the ability of PV technology to provide extremely cheap electricity under the condition of a low system price (below 1 USD/Wp) and a low cost of capital. At the moment of writing these lines, the record was 2,1 USDcents/kWh for PV projects in Chile and Mexico to be built in the coming years, under specific conditions. This project won the bid proposed by local authorities but has not yet been built. Many other winning bids globally reached a level below 3 USDcents/kWh. Low PPAs were granted in 2016 in the USA but with the help of the tax credit. Even in Europe, 2017 saw PPAs going down to less than 4 EURcents/kWh in Spain and less than 5 EURcents/kWh in Germany. Even if all the projects linked to tenders don't represent yet a significant market share, they represent the most competitive PV installations and their share is growing.

COMMENTS ON GRID PARITY AND COMPETITIVENESS

Finally, the concept of Grid Parity remains an interesting benchmark but should not be considered as the moment when PV is competitive by itself in a given environment. On the contrary, it shows how complex the notion of competitiveness can be and how it should be treated with caution. Countries that are approaching competitiveness are experiencing such complexity: Germany, Italy or Denmark for instance, have retail electricity prices that are above the LCOE of a PV system. However, considering the self-consumption and grid constraints, they have not reached competitiveness yet. For these reasons, the concept of Grid Parity should be used with caution and should take into consideration all necessary parameters. Finally, PV remains an investment like many others. The relatively high level of certainty during a long period of time should not hide the possible failures and incidents. Hedging such risks has a cost in terms of insurance and the expected return on investment should establish itself at a level that comprises both the low project risk (and therefore the low expected return) as well as hedging costs.

seven

PV IN THE ENERGY SECTOR

PV ELECTRICITY PRODUCTION

PV electricity production is easy to measure at a power plant but much more complicated to compile for an entire country. In addition, the comparison between the installed base of PV systems in a country at a precise date and the production of electricity from PV are difficult to compare. A system installed in December will have produced only a small fraction of its regular annual electricity output. For these reasons, the electricity production from PV per country that is showed here is an estimate.

Some small countries have taken the lead of the highest PV penetration. The speed at which PV can be deployed has pushed Honduras above the 12% penetration mark in only one year. Penetrations between 4 and 12% are also common in several islands and countries with low energy demand, such as Rwanda or the Kiribati islands but such cases are exceptions.

Italy remains the number one country in the IEA PVPS network with 7,2% of its electricity that will come from PV in 2016. In Germany, with almost 7%, the 41 GW installed in the country produce up to 50% of the instantaneous power demand on some days, and around 14% of the electricity during the peak periods.

Three European countries outside the IEA PVPS network have the ability to produce more than 3% of their electricity demand: Greece (around 7% based on the 2016 installed capacity), the Czech Republic, Romania and the UK. Japan has reached the 4,8% mark, a remarkable level in a country with a modern economy. Belgium just reached the 4 % threshold. Australia remains below the 4 % mark producing the 3,2 % of its electricity thanks to PV.

How much electricity can be produced by PV in a defined country?

- Estimated PV installed and commissioned capacity on 31.12.2016.
- Average theoretical PV production in the capital city of the country (using solar irradiation databases: JRC's PVGIS, SolarGIS, NREL's PVWATT or, when available, country data).
- Electricity demand in the country based on the latest available data.

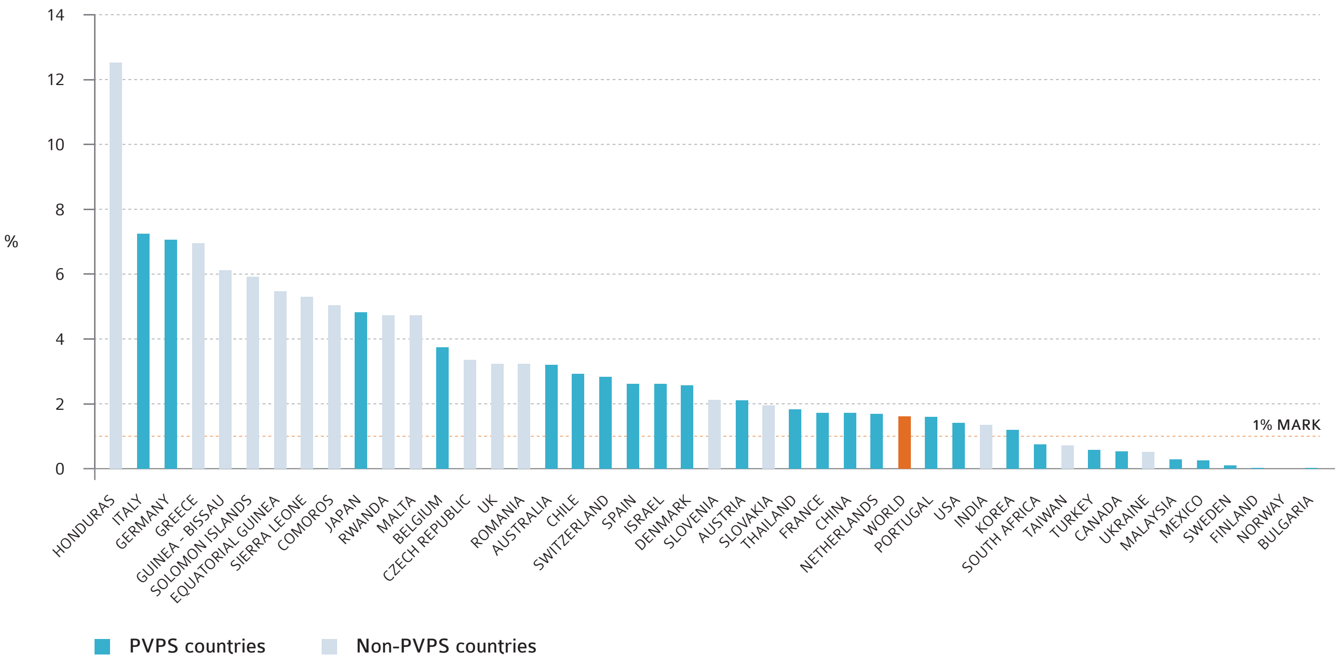
Switzerland, Spain, Denmark and Israel are above the 2% mark, together with Chile, Slovenia and Austria. Slovakia, France, Portugal, Thailand and the Netherlands are still below the 1,5% mark. Also In China in 2016, 1,7% of the electricity demand will be now covered by PV for the first year. Many other countries have lower production numbers, but in total 33 countries produced at least 1% of their electricity demand from PV in 2016.

Figure 31 shows how PV theoretically contributes to the electricity demand in IEA PVPS countries, based on the PV capacity at the end of 2016.

GLOBAL PV ELECTRICITY PRODUCTION

With around 305 GW installed all over the world, PV could produce around 400 TWh of electricity on a yearly basis. With the world's electricity consumption above 22 000 TWh in 2016, this represents close to 2% of the electricity global demand covered by PV.

FIGURE 31: PV CONTRIBUTION TO THE ELECTRICITY DEMAND IN 2016



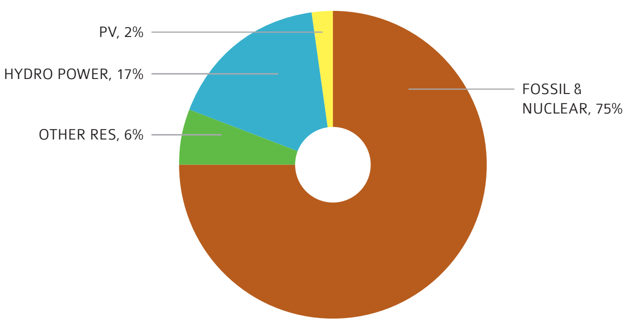
SOURCE SOURCE IEA PVPS & OTHERS.

Figures 32 and 33 compare this number to other electricity sources, and especially renewables. PV represented 33% of the world's newly installed capacity of renewables, excluding hydropower in 2016. In the last sixteen years in the European Union, PV's installed capacity ranked second with more than 100 GW installed, after wind (142 GW), ahead of gas (down to 95 GW) and ahead all other electricity sources, while conventional coal and nuclear were massively decommissioned.

The trend is not so different outside Europe and the speed of transformation increases. In China, PV represented 28% of the new capacity installed in the country in 2016: Out of 120 GW of new power generation capacities installed in 2016, 34,5 GW were photovoltaics. In 2015, China reached 100% of electrification.

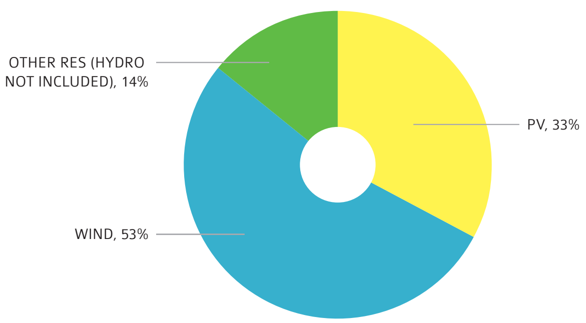
In 2016, Japan installed 8,9 GW (AC) of new power generation capacities including 77,5% of renewables. In the USA renewables represented 20 out of 28,5 GW of new capacities. In Australia, 1,2 GW of power generation capacity was installed in 2016, out of which 73% were PV systems. In Switzerland pump hydro storage was increased by 1 GW in 2016, an interesting sign of the need to storing electricity. Korea installed 4,4 GW of new production capacities but renewable additions came mainly from PV with 0,9 GW out of 1,2 GW installed. In general, the interest is shifting towards renewables.

FIGURE 32: SHARE OF PV IN THE GLOBAL ELECTRICITY DEMAND IN 2016



SOURCE REN21, IEA PVPS.

FIGURE 33: SHARE OF PV IN THE TOTAL RES INSTALLED CAPACITY IN 2016



SOURCE REN21, IEA PVPS.

PV ELECTRICITY PRODUCTION / CONTINUED

TABLE 8: PV ELECTRICITY STATISTICS IN IEA PVPS REPORTING COUNTRIES 2016

COUNTRY	FINAL ELECTRICITY CONSUMPTION 2016 (TWh)	HABITANTS 2016 (MILLION)	GDP 2016 (BILLION USD)	SURFACE (km^2)	AVERAGE IRRADIATION kWh/kWp	PV INSTALLATIONS IN 2016 (MW)	PV CUMULATIVE INSTALLED CAPACITY 2016 (MW)	PV ELECTRICITY PRODUCTION (TWh)	2016 INSTALLATIONS PER HABITANT (W/Hab)	CAPACITY PER HABITANT (W/Hab)	CAPACITY PER KM^2 (kW/km^2)	PV PENETRATION (%)
AUSTRALIA	252	24	1 205	7 741 220	1 400	876	5 985	8,4	36,3	248,1	0,8	3,2%
AUSTRIA	59	9	386	83 879	1 026	171	1 108	1,1	19,5	126,7	13,2	1,9%
BELGIUM*	84	11	466	30 530	990	173	3 423	3,4	15,2	301,6	112,1	4,0%
CANADA	561	36	1 530	9 984 670	1 150	143	2 723	3,1	4,0	75,0	0,3	0,5%
CHILE	74	17	247	756 096	2 020	495	1 071	2,2	29,1	63,0	1,4	2,9%
CHINA	5 920	1 379	11 199	9 562 911	1 300	34 550	78 080	101,5	25,1	56,6	8,2	1,7%
DENMARK	31	6	306	43 090	925	71	858	0,8	12,5	149,8	19,9	2,6%
FINLAND	85	6	237	338 420	838	17	37,4	0	3,2	6,8	0,1	0,0%
FRANCE	483	67	2 466	549 087	1 160	559	7 164	8,3	8,4	107,1	13,0	1,7%
GERMANY	548	83	3 467	357 170	942	1 476	41 186	38,8	17,9	498,2	115,3	7,1%
ISRAEL*	56	9	319	22 070	1 450	130	1 016	2	15,2	118,8	46,0	2,6%
ITALY	308	61	1 850	301 340	1 158	382	19 297	22	6,3	318,4	64,1	7,2%
JAPAN	912	127	4 939	377 962	1 050	7 890	42 041	44	62,1	331,0	111,2	4,8%
KOREA	484	51	1 411	100 266	1 314	904	4 397	6	17,6	85,8	43,9	1,2%
MALAYSIA	141	31	296	330 800	1 200	71,8	336	0	2,3	10,8	1,0	0,3%
MEXICO*	262	128	1 046	1 964 380	1 780	143	389	1	1,1	3,1	0,2	0,2%
NETHERLANDS*	114	17	771	41 500	950	525	2 085	2	30,8	122,5	50,2	1,7%
NORWAY	132	5	371	385 178	800	11	27	0	2,2	5,1	0,1	0,0%
PORTUGAL	51	10	205	92 220	1 600	52	517	1	5,0	50,0	5,6	1,6%
SOUTH AFRICA	238	56	295	1 219 090	1 702	70	1 030	2	1,3	18,4	0,8	0,7%
SPAIN	265	46	1 232	505 940	1 300	58	5 483	7	1,2	118,1	10,8	2,6%
SWEDEN	140	10	511	447 420	950	79	205	0	8,0	20,7	0,5	0,1%
SWITZERLAND	58	8	660	41 285	950	270	1 664	2	32,2	198,8	40,3	2,7%
THAILAND*	181	69	407	513 120	1 355	1 027	2 446	3,3	14,9	35,5	4,8	1,8%
TURKEY*	222	80	858	783 560	1 527	583	849	1,3	7,3	10,7	1,1	0,6%
USA	4 098	324	18 569	9 831 510	1 437	14 762	40 436	58,1	45,6	124,8	4,1	1,4%
WORLD	**23 105**	**7 442**	**75 544**	**134 325 435**	**1 250**	**75 727**	**303 395**	**379,2**	**10**	**41**	**2,3**	**1,6%**

NOTE: THE PV PENETRATION HAS BEEN CALCULATED ACCORDING TO THE GRID CONNECTED PV CUMULATIVE INSTALLED CAPACITY IN 2016.

SOURCE SOURCE IEA PVPS & OTHERS.

ELECTRIC UTILITIES INVOLVEMENT IN PV

In this section, the word "Utilities" will be used to qualify electricity producers and retailers. In some parts of the world, especially in Europe, the management of the electricity network is now separated from the electricity generation and selling business. This section will then focus on the role of electricity producers and retailers in developing the PV market.

In Europe, the involvement of utilities in the PV business remains quite heterogeneous, with major differences from one country to another. In Germany, where the penetration of PV provides already close to 7% of the electricity demand, the behaviour of utilities can be seen as a mix of an opposition towards PV development and attempts to take part in the development of this new business. Companies such as E.ON have established subsidiaries to target the PV on rooftop customers but are delaying the start of their commercial operations. At the end of 2014, E.ON decided to split in two companies, with one of them focusing on renewable energy development; in 2016 RWE decided to opt for the same strategy. Other utilities such as MVV are starting to propose PV and storage-based services. In France, EDF, the main utility in the country has set up a subsidiary that develops utility-scale PV plants in Europe and North America. End 2016, EDF-EN owned close to 1 GW of PV systems in various countries. In addition, another subsidiary of EDF, EDF-ENR, took over the integrated producer of PV modules, Photowatt, present along the whole value chain and restarted its activities with the aim to provide less than 100 MW of PV modules for in-house projects. The same subsidiary offers PV systems for small rooftop applications, commercial, industrial and agricultural applications. Two other major French energy actors are presented in the PV sector: ENGIE (formerly GDF Suez), the French gas and engineering company develops utility-scale PV plants (and has acquired SolaireDirect, a competitive developer active globally) and its subsidiary in Belgium starts to propose PV services for rooftop applications. Total, the French oil and gas giant, which possessed many companies related to PV for years, has acquired SunPower and has integrated solar in its communication. It has created in 2017 a division called Total Solar, aiming at PV development and has acquired SAFT, a french battery manufacturer.

In Italy, the main utility, ENEL, owns a RES-focused subsidiary, ENEL GREEN POWER, which invests and builds utility-scale PV power plants all over the world, including in its home country. At the end of 2016, EGP had more than 1,5 GW of PV power plants in operation and much more in development. It won several competitive tenders in several key countries and appears as one of the leading developers. In addition, it produces in Italy thin-film multi-junction (composed of amorphous and microcrystalline silicon) PV modules through 3SUN, founded as joint venture with Sharp and STMicroelectronics and now totally owned by EGP, using it for in-house projects. In 2017 it announced its willingness to shift the production towards mainly HeteroJunction cells and modules.

In several European countries, small local utilities are taking a positive approach towards the development of PV, as in Sweden or Switzerland by proposing investment in PV plants in exchange of rebates on the electricity bills or free electricity. In Denmark, EnergiMidt made use of capital incentives for a couple of years for its customers willing to deploy PV. In Austria, the utility of the city of Vienna proposes innovative products such as virtual storage for prosumers or the investment in distant PV plants against free electricity.

In Japan, utilities are engaging into the development of PV systems across the country and have started using PV in their own facilities. In China, most utilities are involved in solar development one way or another. Among the big five utilities, PV production used to be a part of the business until the production boomed in the last years, making investments for additional capacities more important.

In Canada, the Calgary Utility developed its Generate Choice Programme where it offers customers a selection of pricing programmes for 1,3 kW systems or more. In Ontario, several utilities are offering solar installations and maintenance programmes for their customers. Roof leasing exists in parallel to the offering of turnkey solutions. Utility involvement offers them a better control on the distribution systems that they operate and the possibility to offer additional services to their customers.

In the USA, in addition to similar offerings, some utilities are starting to oppose PV development, and especially the net-metering system. In Arizona and California, the debate was quite intense in 2013, concerning the viability of net-metering schemes for PV. However, utilities are also sizing opportunities for business and are starting to offer products or to develop PV plants themselves. Third-party investment comes often from private companies disconnected from the utilities.

In Australia, the fast development of PV has raised concerns about the future business model of utilities. Established generators are losing market share, especially during the daytime peak load period where electricity prices used to be quite high. However, the two largest retailers have stepped into the PV business, capturing significant market share.

In addition to conventional utilities, large PV developers could be seen as the utilities of tomorrow; developing, operating and trading PV electricity on the markets. A simple comparison between the installed capacity of some renewable energy developers and conventional utilities shows how these young companies have succeeded in developing many more plants than older companies.

CONCLUSION – A CHALLENGING YEAR

The year 2016 experienced again a significant growth of the PV market and confirmed the Asian leadership on the PV market and industry. PV has entered rapidly into a new era where the PV market concentrates in countries with energy needs and ad hoc policies. Two of the top three markets in 2016 were located in Asia (China and Japan), followed by a booming US market and Europe as a whole. India and many emerging markets can be considered as the fastest growing part of the market.

This trend should be confirmed again in 2017, with Asia consolidating the core of the PV market, and bringing some additional growth, followed by the Americas, India and Europe. With PV development occurring in Latin America, Africa and the Middle East, it becomes clear that in the short term, all continents will experience a sound PV development, with various patterns. It is important to note that new markets spots have popped up in many places around the world, from the Philippines to Abu Dhabi and Jordan or Mexico, confirming the globalization trends.

In Asia, next to China and Japan, Thailand, Korea, Taiwan, Vietnam, the Philippines and many other countries are starting or continuing to develop. India becomes the fifth pole of PV development, and the plans to install 100 GW in the coming years will lead to enough installations to reach that goal. Even if the goal is ambitious, especially in the distributed segments, the announcement in 2017 of large tenders will support the development. The Americas are following at a slower pace, with Latin America starting to engage in PV development in Mexico, Peru, Brazil, Panama, Honduras and of course Chile, the number one market in the region again in 2016. Mexico will most probably lead the pace from 2018 onwards.

The price decrease that has been experienced in the last years restarted in the second quarter of 2016 and continued in 2017. It has brought several countries and market segments close to a real level of competitiveness. This is true in countries where the retail price of electricity in several consumers segments is now higher than the PV electricity's production cost. This is also true in several other countries for utility-scale PV or hybrid systems. However, the distributed segments experience difficulties in many countries, due to the difficulties to set-up sometimes complex regulations for self-consumption. In that respect, the absolute market size for distributed PV applications remained roughly stable from 2011 to 2015 and increase only slightly in 2016 while the utility-scale market boomed significantly. Competitive tenders have also paved the way for low PV electricity prices in several key markets. These declining prices are opening new business models for PV deployment, even if super-low prices cannot be always considered as competitive. PV is more and more seen as a way to produce electricity locally rather than buying it from the grid. Self-consumption opens the door for the large deployment of PV on rooftops, and the transformation of the electricity system in a decentralized way. In parallel, large-scale PV continued to progress, with plant announcements now up to 2000 MW. Each year, larger plants are connected to the grid and plans for even bigger plants are being disclosed. However, PV is not only on the rise in developed countries, it also offers adequate products to bring electricity in places where grids are not yet developed. The decline of prices for off-grid systems offers new opportunities to electrify millions of people around the world who have never benefited from it before.

The challenges are still numerous before PV can become a major source of electricity in the world. The way how distribution grids could cope with high shares of PV electricity, generation adequacy and balancing challenges in systems with high shares of variable renewables, and the cost of transforming existing grids will be at the cornerstone of PV deployment in the coming years. Moreover, the ability to successfully transform electricity markets to integrate PV electricity in a fair and sustainable way will have to be scrutinized. But the trend is clear: PV is now recognized as a competitive electricity source, so competitive that it may dwarf many competitors in the coming years..The price of PV electricity will continue to decline and accordingly, its competitiveness. The quest for PV installation quality will continue and will improve PV system reliability together with lowering the perceived risk of owning and maintaining PV power plants.

Finally, the ability of the PV industry to lower its costs in the coming years and to present innovative products will become the key challenge. Financing new production capacities in a PV market above 100 GW a year will be key. Manufacturing of PV remains a poloitical subject that will have to be scrutinized.

The road to PV competitiveness is open but remains complex and linked to political decisions. Nevertheless, the assets of PV are numerous and as seen in this 22nd edition of the IEA PVPS Trends report, the appetite for PV electricity grows all over the world. The road will be long before PV will represent a major source of electricity in most countries, but as some European countries have shown in recent years, PV has the ability to continue progressing fast and become the major source of electricity in the world.

SURVEY METHOD Key data for this publication were drawn mostly from national survey reports and information summaries, which were supplied by representatives from each of the reporting countries. These national survey reports can be found on the website www.iea-pvps.org. Information from the countries outside IEA PVPS are drawn from a variety of sources and, while every attempt is made to ensure their accuracy, the validity of some of these data cannot be assured with the same level of confidence as for IEA PVPS member countries.

ANNEXES

ANNEX 1: CUMULATIVE INSTALLED PV CAPACITY (MW) FROM 1992 TO 2016

COUNTRY	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
IEA PVPS COUNTRIES																									
AUSTRALIA	7	9	11	13	16	19	23	25	29	34	39	46	52	61	70	82	105	188	571	1377	2415	3226	4088	5109	5985
AUSTRIA	0	0	0	0	0	0	0	0	0	0	0	0	21	24	26	29	32	53	95	187	263	626	785	937	1108
BELGIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	109	648	1066	2105	2800	3058	3153	3250	3423
CANADA	1	1	2	2	3	3	5	6	7	9	10	12	14	17	20	26	33	95	281	558	827	1272	1904	2579	2723
CHILE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	10	221	576	1071
CHINA	0	0	0	0	0	0	0	0	19	24	42	52	62	70	80	100	140	300	800	3500	7060	17740	28380	43530	78080
DENMARK	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3	5	7	17	408	563	606	787	858
FINLAND	0	0	0	0	0	0	0	0	0	0	0,3	0,7	1	1	2	2	3	5	7	8	8	8	8	20	37
FRANCE	2	2	2	3	4	6	8	9	11	14	17	21	24	26	38	76	180	371	1209	2973	4094	4748	5702	6605	7164
GERMANY	3	4	6	7	10	17	22	30	103	223	344	496	1165	2101	2950	4230	6193	10538	17956	25442	33046	36350	38250	39710	41186
ISRAEL	0	0	0	0	0	0,3	0,3	0,4	0,4	0,5	0,5	0,5	0,9	1	1	2	3	25	70	190	237	481	681	886	1016
ITALY	9	12	14	16	16	17	18	18	19	20	22	26	31	38	50	100	496	1277	3605	13141	16796	18198	18606	18915	19297
JAPAN	19	24	31	43	60	91	133	209	330	453	639	860	1132	1422	1708	1919	2144	2627	3618	4914	6632	13599	23339	34150	42041
KOREA	0	0	0	0	0	0	0	0	0	0	5	6	9	14	36	81	357	524	650	729	1024	1555	2481	3493	4397
MALAYSIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	3	34	141	206	264	336
MEXICO	0	0	9	9	10	11	12	13	14	15	16	17	18	19	20	21	22	25	31	40	52	112	179	246	389
NETHERLANDS	0	0,1	0,1	0,3	0,7	1	1	5	9	16	22	40	43	45	48	49	53	64	85	143	363	723	1123	1560	2085
NORWAY	0	0	0	0	0	0	0	6	6	6	6	7	7	7	8	8	8	9	9	10	10	11	13	15	27
PORTUGAL	0	0	0	0	0	0	0	0	0	0	0	2	2	2	4	15	62	110	134	175	244	299	416	465	517
SOUTH AFRICA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	14	22	122	922	960	1030
SPAIN	0	0	1	1	1	1	1	2	2	5	8	13	27	55	167	778	3829	3848	4330	4792	5104	5354	5376	5425	5483
SWEDEN	0,8	1	1	2	2	2	2	3	3	3	3	4	4	4	5	6	8	9	11	15	23	42	78	126	205
SWITZERLAND	5	6	7	8	8	10	12	13	15	18	20	21	23	27	30	36	48	74	111	211	437	756	1061	1394	1664
THAILAND	0	0	0	0	0	0	0	0	0	0	0	0	0	24	30	32	33	43	49	242	388	824	1299	1420	2446
TURKEY	0	0	0	0	0	0	0	0	0,1	0,3	0,6	1	2	2	3	3	4	5	6	7	12	18	58	266	849
USA	0	0	0	0	0	0	0	0	0	0	0	0	111	190	295	455	753	1188	2040	3959	7328	12079	18317	25674	40436
TOTAL IEA PVPS	46	60	84	103	131	178	236	340	569	839	1193	1623	2749	4151	5593	8077	14618	22029	36752	64752	89628	121914	157251	198363	263853
TOTAL NON IEA PVPS	0	0	0	0	0	0	0	0	1	2	3	17	29	34	38	49	135	729	2824	5417	9906	15281	19715	29306	39542
TOTAL	46	60	84	103	131	178	236	340	570	841	1196	1640	2778	4185	5631	8126	14753	22758	39576	70168	99534	137195	176966	227669	303395

SOURCE SOURCE IEA PVPS & OTHERS.

ANNEX 2: ANNUAL INSTALLED PV CAPACITY (MW) FROM 1992 TO 2016

COUNTRY	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
											IEA PVPS COUNTRIES														
AUSTRALIA	7	2	2	2	3	3	4	3	4	4	6	7	7	8	10	12	22	83	383	806	1038	811	862	1022	876
AUSTRIA	0	0	0	0	0	0	0	0	0	0	0	0	21	3	2	3	4	20	43	92	76	363	159	152	171
BELGIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	85	539	418	1040	694	259	94	97	173
CANADA	1	0,3	0,3	0,4	0,7	0,8	1	1	1	2	1	2	2	3	4	5	7	62	187	277	269	445	633	675	143
CHILE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	7	210	355	495
CHINA	0	0	0	0	0	0	0	0	19	5	19	10	10	8	10	20	40	160	500	2700	3560	10680	10640	15150	34550
DENMARK	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0,2	0,2	0,1	1	3	10	391	156	42	181	71
FINLAND	0	0	0	0	0	0	0	0	0	0	0,3	0,4	0,3	0,3	0,6	0,5	0,6	2	2	2	0	0	0	12	17
FRANCE	2	0,3	0,3	0,5	2	2	2	2	2	3	3	4	3	2	12	38	104	191	838	1764	1120	654	954	903	559
GERMANY	3	1	1	1	4	6	5	8	73	119	121	152	669	935	850	1280	1963	4345	7418	7485	7604	3304	1900	1461	1476
ISRAEL	0	0	0	0	0	0,3	0	0,1	0	0	0	0	0,4	0,2	0,3	0,5	1	22	46	120	47	244	200	205	130
ITALY	3	4	2	2	0,3	0,7	0,9	0,7	0,6	1	2	4	5	7	13	50	396	781	2328	9536	3655	1402	409	308	382
JAPAN	19	5	7	12	16	32	42	75	122	123	184	223	272	290	287	210	225	483	991	1296	1718	6968	9740	10811	7890
KOREA	0	0	0	0	0	0	0	0	0	0	5	0,6	3	5	22	45	276	167	127	79	295	531	926	1011	904
MALAYSIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,5	0,2	0,1	0,3	0,5	1	32	107	65	58	72
MEXICO	0	0	9	0,4	0,8	1	1	0,9	1	1	1	1	1	0,5	1	1	1	3	6	9	12	60	67	67	143
NETHERLANDS	0	0,1	0,1	0,2	0,4	0,3	0	4	3	8	6	18	4	2	2	1	4	11	21	58	220	360	400	437	525
NORWAY	0	0	0	0	0	0	0	6	0,3	0,2	0,2	0,2	0,3	0,4	0,4	0,3	0,3	0,4	0,4	0,4	0,5	0,6	2	2	11
PORTUGAL	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	11	47	48	24	41	69	55	117	49	52
SOUTH AFRICA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	5	8	100	800	38	70
SPAIN	0	0	1	0	0	0	0	1	0	2	3	5	14	28	112	611	3051	19	481	462	312	250	23	49	58
SWEDEN	1	0,2	0,3	0,3	0,2	0,3	0,2	0,2	0,2	0,2	0,3	0,3	0,3	0,4	0,6	1	2	1	2	4	8	19	35	48	79
SWITZERLAND	5	1	0,9	0,8	0,9	1	2	2	2	2	2	2	2	4	3	7	12	26	37	100	226	319	305	333	270
THAILAND	0	0	0	0	0	0	0	0	0	0	0	0	0	24	7	2	0,9	10	6	193	145	436	475	121	1027
TURKEY	0	0	0	0	0	0	0	0	0,1	0,2	0,3	0,4	0,5	0,5	0,5	0,5	0,7	1	1	1	5	6	40	208	583
USA	0	0	0	0	0	0	0	0	0	0	0	0	111	79	105	160	298	435	852	1919	3369	4751	6238	7357	14762
TOTAL IEA PVPS	41	14	24	19	28	47	58	104	229	270	354	431	1126	1402	1442	2484	6541	7411	14723	28000	24876	32286	35337	41112	65490
TOTAL NON IEA PVPS	0	0	0	0	0	0	0	0	1	1	1	13	13	4	5	10	86	594	2095	2593	4489	5375	4434	9591	10237
TOTAL	41	14	24	19	28	47	58	104	230	271	355	444	1138	1407	1447	2494	6627	8005	16818	30592	29366	37661	39771	50703	75727

SOURCE SOURCE IEA PVPS & OTHERS.

ANNEX 3: REPORTED PRODUCTION OF PV MATERIALS, CELLS AND MODULES IN 2016 IN SELECTED IEA PVPS COUNTRIES

									MODULE PRODUCTION (MW)		
COUNTRY[1]	SOLAR PV GRADE SI FEEDSTOCK PRODUCTION (TONNES)	SOLAR PV GRADE SI FEEDSTOCK PRODUCTION CAPACITY (TONNES/YEAR)	PRODUCTION OF INGOTS (TONNES)	INGOTS PRODUCTION CAPACITY (TONNES/ YEAR)	PRODUCTION OF WAFERS (MW)	WAFER PRODUCTION CAPACITY (MW/YEAR)	CELL PRODUCTION (ALL TYPES, MW)	CELL PRODUCTION CAPACITY (MW/YEAR)	WAFER BASED (SC-SI & MC-SI)	THIN-FILM (A-SI & OTHER)	MODULE PRODUCTION CAPACITY (ALL TYPES, MW/YEAR)
AUSTRALIA									20		60
AUSTRIA											
CANADA	350										252
CHINA			-				51 000	63 000			79 000
DENMARK											
FINLAND									5		20
FRANCE											
GERMANY											
ITALY											
JAPAN	NA	NA			NA	NA	2 116	3 790	291	911	4 130
KOREA		82 000		2 900		2 380		3 705	5 810		5 810
MALAYSIA	NA	20 000	NA	124			NA	3 245	NA	NA	5 944
NORWAY	6 500	4 500 + 350		NA		280					
SPAIN											
SWEDEN											
SWITZERLAND								40			NA
THAILAND											
USA	29 624						776	801	1 109	590	1 926

NOTES:
1 ALTHOUGH A NUMBER OF IEA PVPS COUNTRIES ARE REPORTING ON PRODUCTION OF FEEDSTOCK, INGOTS AND WAFERS, CELLS AND MODULES, THE PICTURE FROM THE NATIONAL SURVEY REPORTS OF THE PV INDUSTRY SUPPLY CHAIN IS BY NO MEANS COMPLETE AND CONSEQUENTLY THESE DATA ARE PROVIDED MORE AS BACKGROUND INFORMATION.

SOURCE IEA PVPS, RTS CORPORATION.

ANNEX 4: AVERAGE 2016 EXCHANGE RATES

COUNTRY	CURRENCY CODE	EXCHANGE RATE (1 USD =)
AUSTRALIA	AUD	1,35
AUSTRIA, BELGIUM, FINLAND, FRANCE, GERMANY, ITALY, THE NETHERLANDS, PORTUGAL, SPAIN	EUR	0,90
CANADA	CAD	1,33
CHINA	CNY	6,64
DENMARK	DKK	6,73
ISRAEL	ILS	3,84
JAPAN	JPY	108,80
KOREA	KRW	1 161,22
MALAYSIA	MYR	4,14
MEXICO	MXN	18,68
NORWAY	NOK	8,41
SWEDEN	SEK	8,56
SWITZERLAND	CHF	0,99
THAILAND	THB	35,29
TURKEY	TRY	3,02
UNITED STATES	USD	1,00

SOURCE XE.

LIST OF FIGURES & TABLES

WHAT IS THE IEA PVPS?

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organisation for Economic Cooperation and Development (OECD). The IEA carries out a comprehensive programme of energy cooperation among its 31 members 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 collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems."

In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct "Tasks", that 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. The participating countries are Australia, Austria, Belgium, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey and the United States of America. The European Commission, SolarPower Europe (former EPIA), the Solar Electric Power Association, the Solar Energy Industries Association and the Copper Alliance are also members.

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