IEA INTERNATIONAL ENERGY AGENCY

TRENDS 2018

IN PHOTOVOLTAIC APPLICATIONS

23RD EDITION 2018

Survey Report of Selected IEA Countries between 1992 and 2017

PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

Report IEA PVPS T1-34:2018

COVER IMAGE
Cité Musicale de L'île Séguin in Paris. The sail of the auditorium is solar and move around following the path of the sun.

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 non technical 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 23rd international survey. It provides an overview of PV power systems applications, markets and production in the reporting countries and elsewhere at the end of 2017 and analyses trends in the implementation of PV power systems between 1992 and 2018. 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 2018 in Photovoltaic Applications", are valid at the time of publication. Please note that all figures have been rounded.

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FOREWORD

On behalf of the IEA PVPS Programme, welcome to the 23rd international survey report on Trends in Photovoltaic (PV) Applications!

Since its inception in 1992, the series of IEA PVPS Trends reports now covers the unique analysis of the last 25 years of global PV market development. IEA PVPS is proud to be a key witness of the very dynamic development that photovoltaics has undergone in the last quarter of a century, thereby tracing the very start of the global energy turnaround that the world is now experiencing, and which will continue to do so over the next 25 years.

This year's report covers the market and industry development up to 2017 which has been another record-breaking year. For the first time, close to 100 GW of PV power systems have been installed globally in one year, bringing the total installed capacity to over 400 GW and confirming the annually new installed PV capacity as the number one over all other energy technologies.

Once again, a key driver of this remarkable result has been the development in China (53,1 GW of installed capacity in 2017), followed by the United States (10,7 GW), India (9,1 GW), Japan (7,5 GW) and – for the first time among the top five PV countries – Turkey (2,6 GW). This picture confirms that – besides the key role that China plays – an important part of the growth comes from emerging PV markets, namely in the Asia-Pacific region. The US market was lower than in 2016 (14,8 GW) while established markets such as Japan and Europe remained rather stable. Nine countries installed more than 1 GW in 2017 and 27 countries reached a cumulative capacity of 1 GW and more.

On the cost side, record PPAs have been announced at below 2 USDcents per kWh, confirming the increasing competitiveness that PV can reach under best conditions. With further cost reductions to be expected in the coming years, this trend is very likely to continue bringing PV to the cheapest option for electricity generation. It is, however, equally important to point out that average PV life cycle costs of electricity are somewhat higher and often still strongly depend on the regulatory framework conditions. Best evidence for this observation is given by the change of the framework conditions that took place in China in May 2018, thereby strongly affecting this particular market.

Overall, the policy driven conditions globally tend to diversify, in particular for smaller systems, where self-consumption and storage options are gaining importance. While policy remains relevant, a shift to market-oriented framework conditions can be observed in many countries. As part of this trend, new business models are being introduced leading to further diversification. All of these developments are accompanied by continuous technology and product evolution, making PV a growing player in the energy field. With its rising level of penetration in electric grids, PV is more and more affecting electricity systems as a whole, and the integration into various technical and market environments becomes crucial.

As a last number to remember, at the end of 2017, PV is estimated to provide about 2,5% of the global electricity supply and in about 30 countries, PV contributes between 1% and 10% to the electricity consumption. These are just a few highlights of the wealth of information that this 23rd edition of the IEA PVPS Trends report hopes to provide to you!

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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 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 97% 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 2017 21% in labs. Organic thin-film PV cells, using dye or organic semiconductors, have created interest and research, development and demonstration activities are underway. In June 2018 , perovskites solar cells have reached efficiencies of 27,3% in labs but have not yet resulted in stable market products. Tandem cells based on perovskites are currently researched, with either a crystalline silicon base or a thin-film base and could hit the market sooner than pure perovskites products.

Photovoltaic modules are typically rated between 50 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 17 and 22,7%. 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

PV TECHNOLOGY / CONTINUED

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 16% (CdTe). CPV modules offer now efficiencies above 38%.

Bifacial PV modules are producing light on both sides of the panel, and when mounted on a surface which albedo reflects enough light, could lead to significant increases in energy production, estimated to a maximum of 15%. However, with few installations at the end of 2017, bifaciality remains a niche which potential seems untapped.

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.

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 overcharged 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 seven 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 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. Floating PV systems are developing fast and can be associated with existing grid connections for instance in the case of dam vicinity. Agricultural PV is also developing fast to combine crops and energy production in the same site.

VIPV or PV in vehicles in the latest PV segment to develop, with some high potential on cars, trucks, ships and more. Decarbonization constraints are pushing for reduced GHG emissions in the transport sector, with a possible emphasis on embedded PV.

two

PV MARKET DEVELOPMENT TRENDS

More than twenty years of PV market development have resulted in the deployment of over 403 GW of PV systems throughout 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 global PV installed capacity represented 403,3 GW of cumulative PV installations altogether, mostly grid-connected, at the end of 2017. The IEA PVPS countries represented 348,1 GW. The other key markets, in total 37 countries that have been considered and are not part of the IEA PVPS Programme, represented 55,2 additional GW.

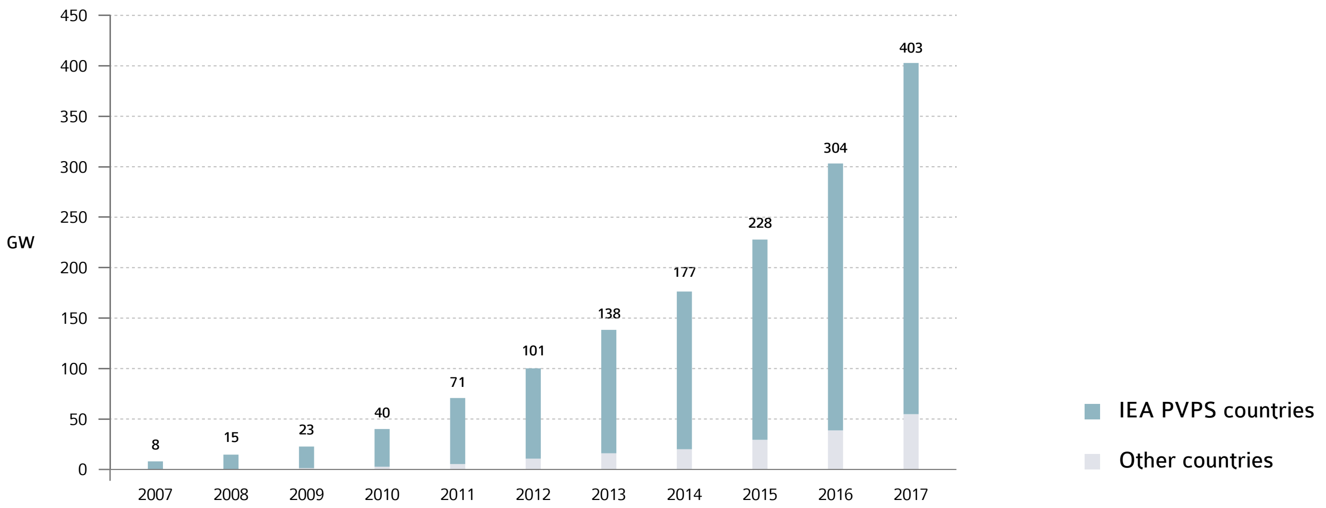
A historical part of these 55,2 GW is located in Europe but other countries came in recent years: UK with almost 12,7 GW, Greece with 2,6 GW, the Czech Republic with 2,2 GW installed, Romania with 1,4 GW, Bulgaria with almost 1 GW, Ukraine with 0,9 GW and Slovakia close to the 0,5 GW mark. The other major countries that accounted for the highest cumulative installations at the end of 2017 are India with more than 18 GW, Pakistan with an estimated 1,9 GW, Taiwan with 1,7 GW, Brazil with 1,2 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 2017 outside the ones mentioned above. According to a paper released in 2018.[1]

27 countries had at least 1 GW installed, 66 countries had a least 100 MW cumulative at the end of 2017 and 131 countries had more than 10 MW.

Presently it appears that 98,95 GW represents the minimum installed by end of 2017 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., 2018.

FIGURE 1: EVOLUTION OF CUMULATIVE PV INSTALLATIONS (GW)



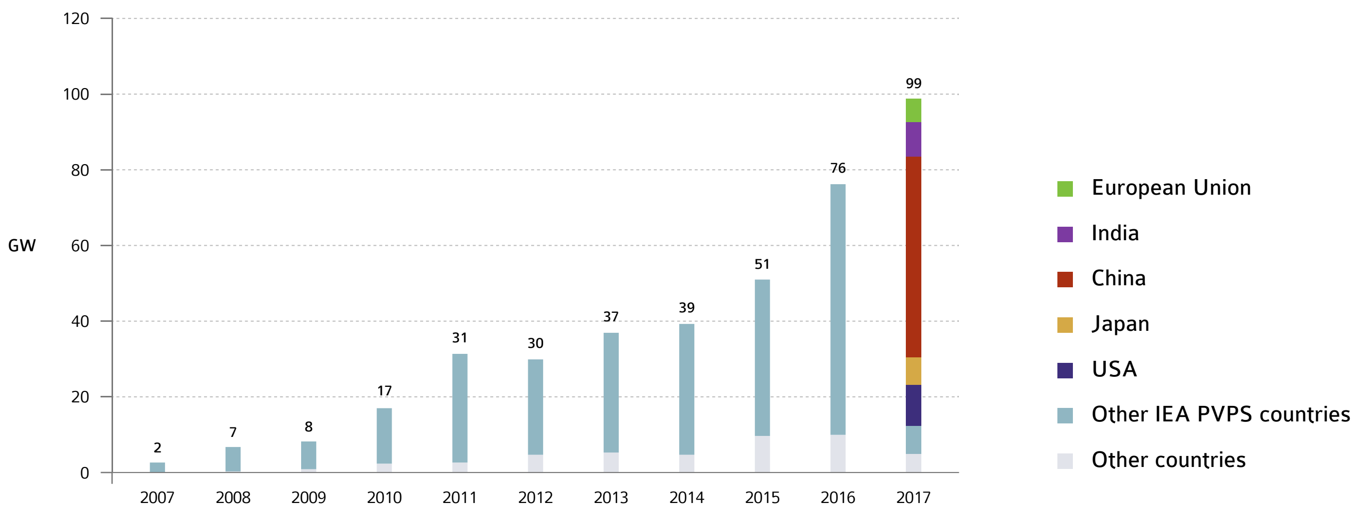
SOURCE IEA PVPS & OTHERS.

THE MARKET EVOLUTION

The 27 IEA PVPS countries installed at least 83,4 GW in 2017. While they are more difficult to track with a high level of certainty, installations in non IEA PVPS countries contributed an amount of 15,5 GW. The remarkable trend of 2017 is again the significant growth of the global PV market after the massive growth experienced during 2015-2016. With 403,3 GW, the installed capacity grew by around 33% in 2017, again breaking the record level from 2016.

For the fifth year in a row, China is in first place and installed more than 53,1 GW in 2017, according to the National Energy Administration; a record level that is significantly higher than the 34,6 GW that placed the country in first place in 2016. China experienced a significant growth again in 2017 and their installation numbers grew mostly thanks to distributed installations. The total installed capacity in China reached 131,1 GW, and confirms the country as the key leader.

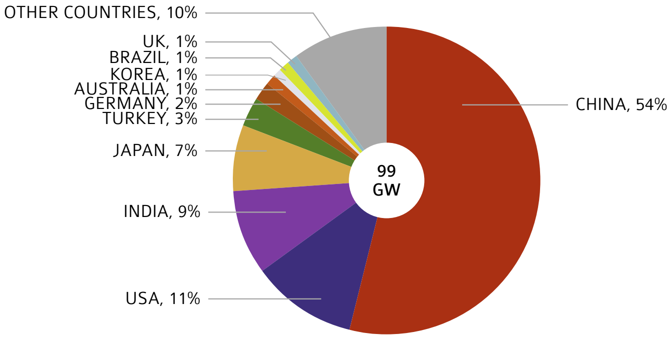
FIGURE 2: EVOLUTION OF ANNUAL PV INSTALLATIONS (GW)



SOURCE IEA PVPS & OTHERS.

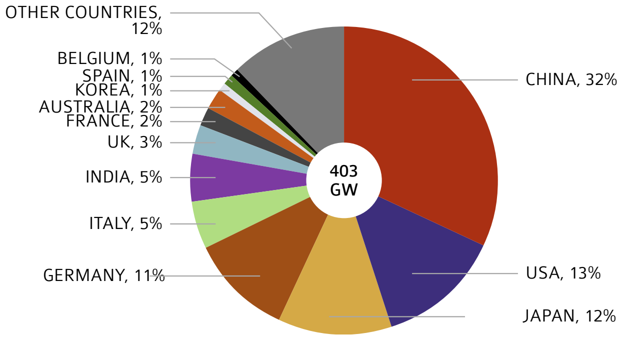
THE MARKET EVOLUTION / CONTINUED

FIGURE 3: GLOBAL PV MARKET IN 2017



SOURCE IEA PVPS & OTHERS.

FIGURE 4: CUMULATIVE PV CAPACITY END 2017



SOURCE IEA PVPS & OTHERS.

The USA is in second place this year again with 10,7 GW installed, out of which 6,2 GW were installed as utility-scale plants. Third is India with 9,1 GW installed, a significant growth compared to 2016, with mostly utility-scale plants installed.

The market in Japan slightly decreased to 7,5 GW installed in the country in 2017. From the record-high level of 10,8 GW in 2015.

The European Union went down to the fifth place, with around 6,1 GW installed, down from the already decreasing 6,2 GW from 2016 and far from the 2011 level.

Together, these five leading countries or block of countries represented 88% of all installations recorded in 2017 and 90% in terms of installed capacity. This shows how the global PV market remains concentrated within 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, Germany (sixth globally) scored the first rank again amongst European countries. It saw its annual installed capacity growing to 1,8 GW from 1,49 GW in 2016, well below the level that was reached already in 2008. The total installed PV capacity has now reached 42,4 GW.

Turkey ranked fifth with 2,6 GW installed in 2017, a major increase compared to previous years and thus confirming the country's potential. Korea with 1,37 GW ranks in seventh position, followed by Australia with 1,3 GW.

The last country to reach the GW mark in 2017 was Brazil (ninth), which installed slightly more than 1 GW, bringing the total installed capacity in the country to 1,1 GW. The tenth position went to the UK with slightly less than 954 MW.

No additional country installed more than 1 GW in 2017, showing that while the PV market reaches new countries, a very large part of the market remains concentrated in the hands of the top countries.

Some countries that reached the top 10 in the last years, such as Thailand or the Philippines left this part of the rankings.

Together, these 10 countries cover 91% of the 2017 world market, a figure that has remained stable for the last few years. Moreover, the level of installation required to enter the top 10 remained at a similar level since 2014; from 843 MW, it went down to 675 MW in 2015, rose again to 759 MW in 2016 and reached 954 MW in 2017, a sign that the growth of the global PV market has been driven by top countries, while others are contributing marginally, still in 2017; fueling fears for the market stability if one of the top three markets would experience a slowdown. This is exactly what happened on May 31, 2018, when China decided to control its PV market.

Behind the top 10, some countries installed significant amounts of PV. France installed 875 MW, increasing its installation rate again compared to the previous years, thanks to important policy changes.The Netherlands installed 853 MW, Chile (565 MW), Italy (414 MW), Belgium (289 MW), Mexico (285 MW), Thailand (251 MW), Canada (249 MW) Switzerland (242 MW), Austria (173 MW), Sweden (118 MW) and Israel (103 MW). .

Among these countries, some have already reached high PV capacities due to past installations. This is the case for Italy that tops 19,7 GW but also for Belgium with 3,8 GW, the Netherlands (2,9 GW) and Thailand (2,7 GW), Romania with 1,4 GW, Brazil with 1,1 GW and Israel is approaching 1 GW.

In Europe, several other countries where the PV market has developed in the last years, have performed in various ways. Some countries that grew dramatically over recent years have now stalled or experienced limited additions: Spain saw its market growing to 103,8 MWac and now totals 4,8 GWac of PV systems (respectively DC calculation 114 MWdc and 5,3 GWdc). The Czech Republic had 2,2 GW but installed only 20 MW in 2017. In Denmark, the market that experienced a rebound due to utility-scale installations in 2015 went down again at 60,7 MW: the distributed PV market that developed thanks to the net-metering scheme remained at a low level. Finland reached 80,4 MW of cumulative installed capacity with markets growing at a low level.

In Asia, many other countries in the region have started to implement PV policies. Malaysia installed 60 MW in 2017 due to numerous support mechanisms. Taiwan installed 523 MW in a growing market that is now supported by pro-solar policymakers. The market in the Philippines went down to 5 MW following the boom of 2016 and Thailand went down again to 251 MW, with a total installed capacity of 2,7 GW. Other markets have shown signs of potential growth such as Pakistan with an estimated 900 MW or Bangladesh with 26 MW.

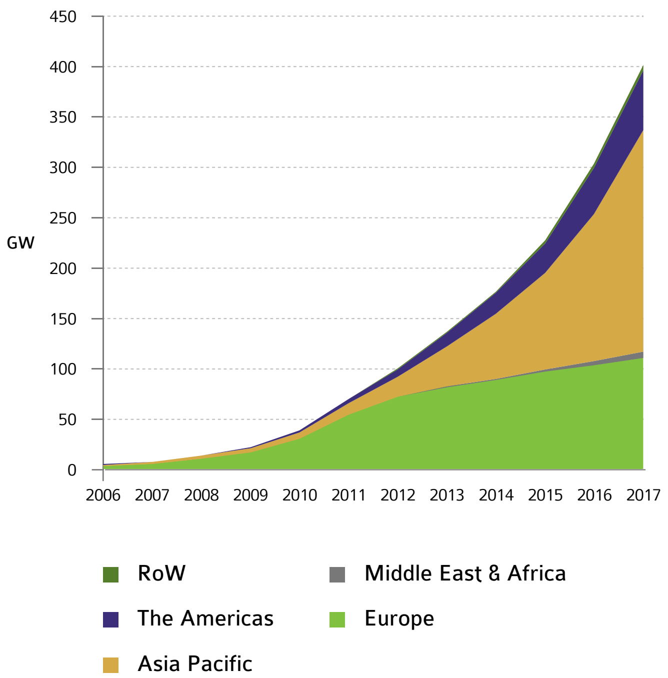
In Latin America, Chile installed 892 MW in 2017. Projects are popping up in Brazil with 1 GW installed in 2017, making it the leading market in Latin America). Honduras installed 391 MW in 2015, but this outcome was not repeated. The real PV development of grid-connected PV plants has finally started and additional countries have installed dozens of MW. Among the most promising prospects in the region, Mexico installed close to 285 MW but several GW have been granted to developers, which might transform the country into a second 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 117 MW. After the 200 MWac plant in Dubai, the 800 MW ac was under construction with the first 300 MW phase going online in 2018. In Abu Dhabi, 300 MWac were tendered in 2018. Finally, Africa also sees PV deployment, with Algeria having installed 54 MW in 2016 and 80 MW more in 2017. South Africa installed around 13 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, but with double-digit MW markets.

A TRULY GLOBAL MARKET

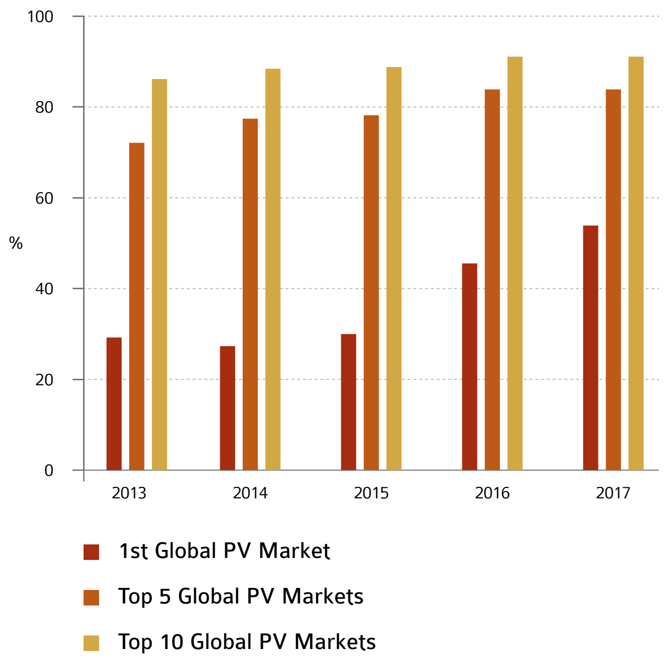
While large markets such as Germany or Italy have exchanged the first two positions from 2010 to 2012, China, Japan and the USA scored the top three positions from 2013 to 2016, with the USA jumping to second place in 2016. In 2017, India took the third spot from Japan. Seven of the top 10 leaders in 2012 are still present in 2017 while the others have varied from one year to another. Turkey and Brazil joined for the first time in 2017. The UK entered the top 10 in 2013 and left it in 2017, Korea in 2014 and is still there, and Thailand came in 2016 to leave in 2017. 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-sized countries with impressive and unsustainable market evolutions declined, especially in Europe but some booming markets in 2017 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

FIGURE 5: EVOLUTION OF REGIONAL PV INSTALLATIONS (GW)



SOURCE IEA PVPS & OTHERS.

FIGURE 6: EVOLUTION OF MARKET SHARE OF TOP COUNTRIES



SOURCE IEA PVPS & OTHERS.

THE MARKET EVOLUTION / CONTINUED

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 and Australia confirmed their market potential, as in 2015. However, the required market level for entry into this top 10 that grew quite fast until 2012, declined until 2015 and increased slightly in 2017. In 2017, 954 MW were necessary to reach the top 10, compared to 843 MW in 2012, while the global PV market surged from 30 to almost 99 GW at the same time. The number of GW markets that declined in 2014 to only five grew again to nine in 2017. Some countries were rather close to the 1 GW mark (UK, France, etc.) in 2017 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 2017, but their share is growing rapidly.

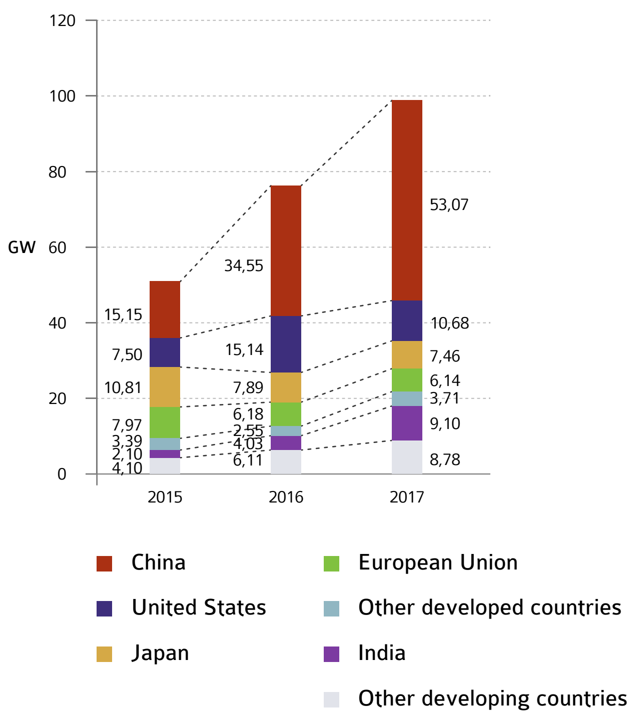
UTILITY-SCALE PROJECTS GROWING BUT AT A SLOWER PACE

The most remarkable trend of 2017 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 2017 with more than 61 GW, compared to only 37 GW two years earlier. Utility-scale continued to grow to around 230 GW of cumulative installed capacity but for the first time in years, distributed PV also grew significantly, up to 37 GW in 2017. Many countries are proposing new tenders, including Spain, 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). In 2018, Spain started to become attractive for utility-scale PV plants financed with wholesale market electricity sales only, which could shape the PV market differently in the coming years.

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 states in India 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, even if the distributed PV market was stable for five years. It has been oscillating around 16-19 GW since 2011, until China succeeded in developing its own distributed market. With more than 36,8 GW globally, the distributed PV market is finally on the rise. The US and European markets are currently and progressively transitioning towards self-consumption while new business models are appearing.

FIGURE 7: 2015 - 2017 GROWTH PER REGION



SOURCE IEA PVPS & OTHERS.

LARGEST ADDITIONS EVER

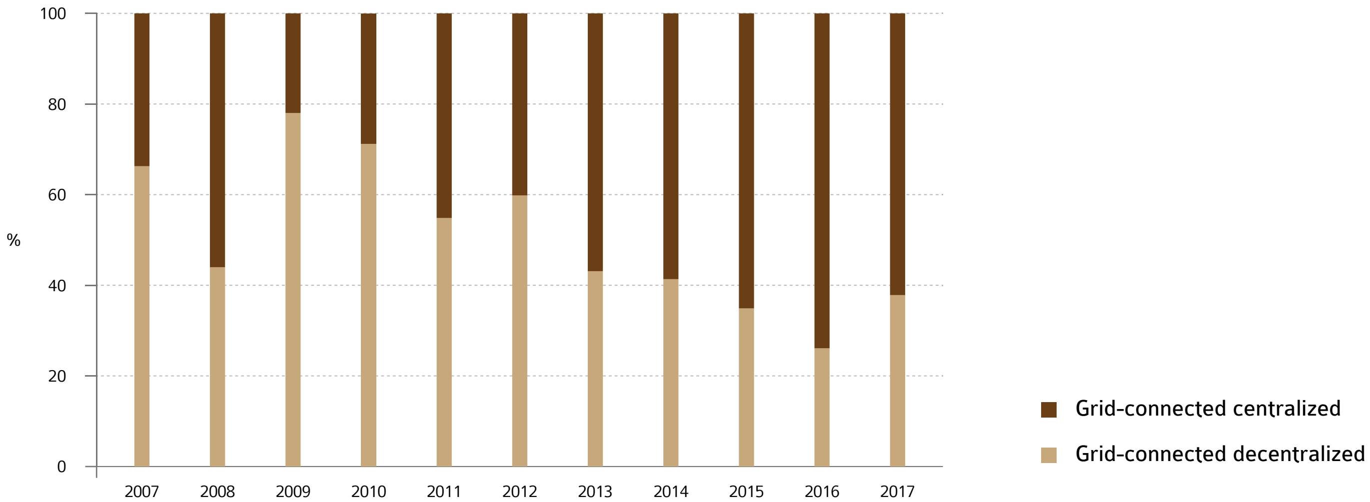
The paradox of PV developing thanks to utility-scale installations is hidden by the remarkable progress of many markets. Italy's record of 9,3 GW yearly installed power was beaten in 2013 by China with its 10,95 GW; but also by Japan in 2015 with 10,8 GW. Then, even more by China in 2015 that installed 15,15 GW, and again in 2016 with 34,5 GW and 53,1 GW in 2017. With one country, China, reaching levels of installations never seen before and higher than the global PV market until 2015, the PV market is in danger of concentration and would require more development.

TABLE 1: EVOLUTION OF TOP 10 PV MARKETS

RANKING	2015	2016	2017
1	CHINA	CHINA	CHINA
2	JAPAN	USA	USA
3	USA	JAPAN	INDIA
4	UK	INDIA	JAPAN
5	INDIA	UK	TURKEY
6	GERMANY	GERMANY	GERMANY
7	KOREA	THAILAND	KOREA
8	AUSTRALIA	KOREA	AUSTRALIA
9	FRANCE	AUSTRALIA	BRAZIL
10	CANADA	PHILIPPINES	UK
MARKET LEVEL TO ACCESS THE TOP 10			
	675 MW	683 MW	954 MW

SOURCE IEA PVPS & OTHERS.

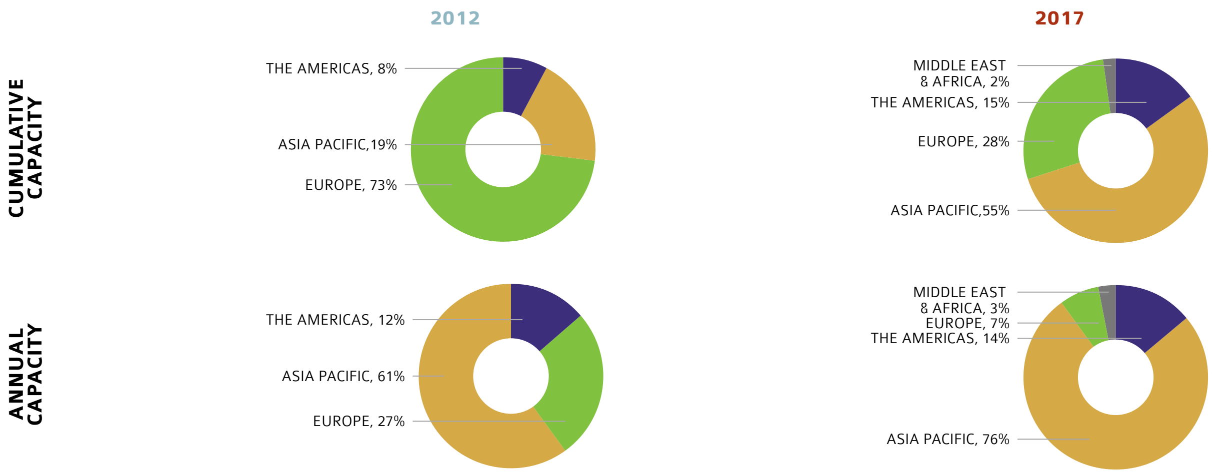
FIGURE 8: ANNUAL SHARE OF CENTRALIZED AND DECENTRALIZED GRID-CONNECTED INSTALLATIONS 2007 - 2017



SOURCE IEA PVPS & OTHERS.

THE MARKET EVOLUTION / CONTINUED

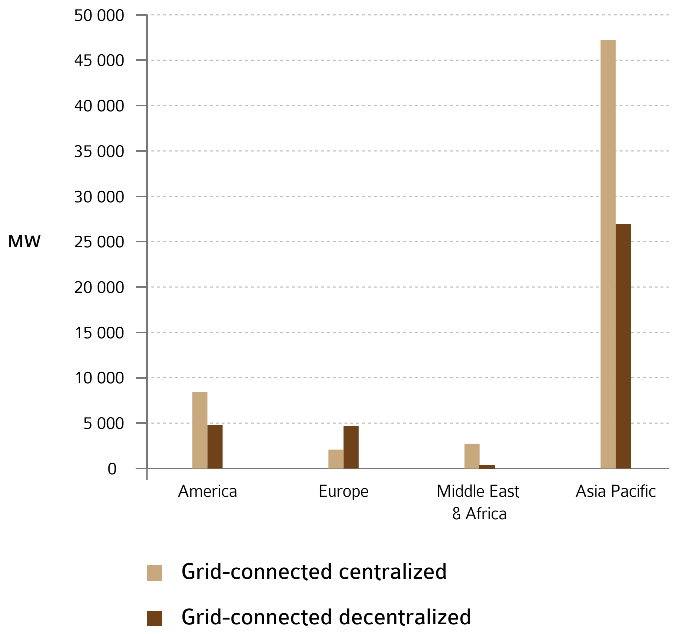
FIGURE 9: EVOLUTION OF ANNUAL AND CUMULATIVE PV CAPACITY BY REGION 2012 - 2017 (MW)



	CUMULATIVE CAPACITY (MW)						ANNUAL CAPACITY (MW)					
REGION	2012	2013	2014	2015	2016	2017	2012	2013	2014	2015	2016	2017
THE AMERICAS	8 107	13 629	20 820	29 905	46 062	59 224	3 540	5 522	7 191	9 085	16 157	13 162
ASIA PACIFIC	19 208	40 048	63 983	95 465	146 192	220 318	7 980	20 840	23 935	31 483	50 727	74 126
EUROPE	72 313	82 274	88 769	97 261	103 949	110 678	18 017	9 961	6 494	8 492	6 689	6 729
MIDDLE EAST & AFRICA	337	692	1 813	2 560	3 969	6 842	112	355	1 121	747	1 409	2 873
REST OF THE WORLD	655	1 081	1 505	2 718	4 175	6 232	263	426	424	1 213	1 457	2 056

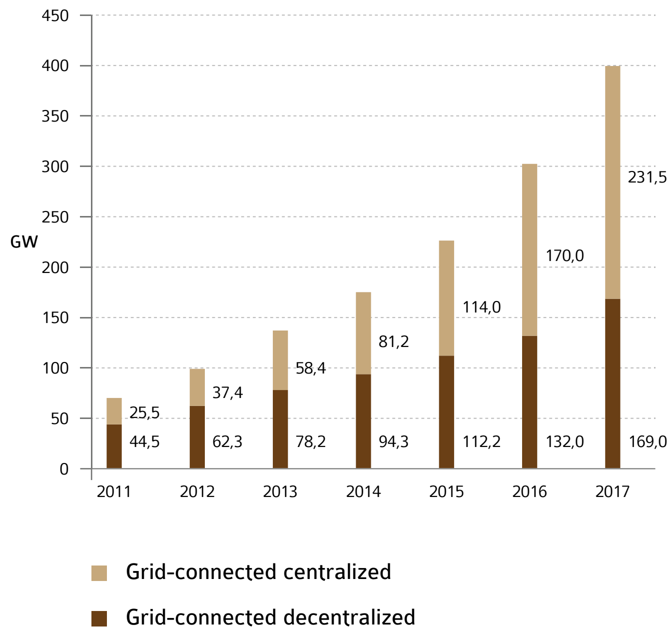
SOURCE IEA PVPS & OTHERS.

FIGURE 10: GRID-CONNECTED CENTRALIZED & DECENTRALIZED PV INSTALLATIONS BY REGION IN 2017



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

FIGURE 11: CUMULATIVE EVOLUTION OF GRID CONNECTED PV INSTALLATIONS 2011 - 2017



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. Numbers for off-grid applications are generally 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 in any case.

Nevertheless, off-grid applications are developing more rapidly in several countries than in the past and some targeted support has been implemented. Even in some developed countries, regulations constraining self-consumption have led to residential homeowners in Spain or Portugal for instance to go for off-grid PV. However, this relates more to traditional PV grid connected systems than the usual off-grid applications.

In Australia, 36 MW of off-grid systems have been installed in 2017, 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 2 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 increasing 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 188 MW of PV at the end of 2017 for a total population of 840 000. While this represents roughly 60% of the penetration of PV in Germany, the capacity of the grid on a small island to absorb fast production and consumption changes is much more challenging. 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 2017 with at least 180 MW installed, providing basic electricity needs for more than thirty million people.

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

India had 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. Such poverty alleviation programs have already led to, in some countries, off-grid systems with back-up (either diesel generators or chemical batteries), which represent an alternative in order to bring the grid into remote areas; representing several GW of PV installations. This continued in 2017.

THE ENERGY STORAGE MARKET

While 2015 was a year of significant announcements with regard to electricity storage, in comparison, 2016 and 2017 delivered little progress. 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 remains small. As a matter of fact, only Germany has incentives for battery storage in PV systems, Italy has a tax rebate and some cantons in Switzerland have subsidy schemes. In Germany, the installation of storage systems funded reached 20 000 in 2017. However, more systems have been installed without incentives. In August 2018, the 100 000 installations threshold was reached.

THE MARKET EVOLUTION / CONTINUED

In 2017, Australia confirmed its place as is a leading country for batteries. Over 20 000 residential energy storage installations took place in 2017, and the world's largest Lithium-ion battery was installed in South Australia in under 100 days. This saw the market reach over 300 MWh.

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 at the moment. 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 this respect, the development of solar heating and cooling hasn't experienced major developments in 2017, contrary to electric mobility that starts to develop quickly 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 1,2 million sold during the year 2017, the automotive sector is moving rapidly towards connecting to the electricity industry.

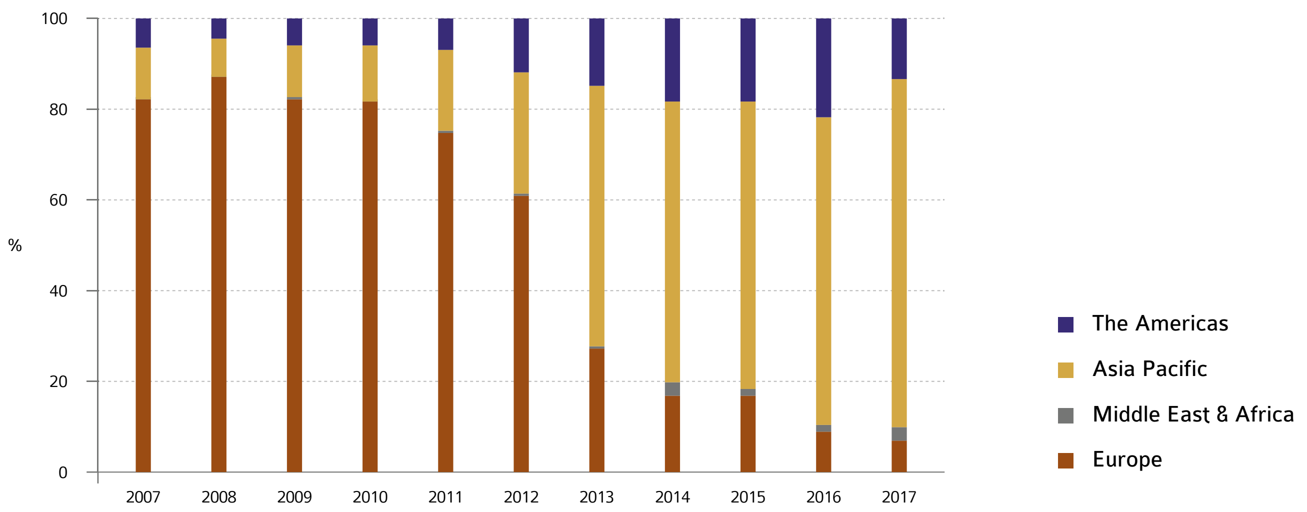
The role of PV as an enabler of that energy transition is more and more obvious and the idea of powering mobility with solar is becoming slowly a reality thanks to joint commercial offers for PV and storage.

PV DEVELOPMENT PER REGION AND SEGMENT

The evolution of grid-connected PV towards a balanced segmentation between centralized and decentralized PV reversed course in 2013, continued its trend until 2016, then reversed course in 2017. Centralized PV had evolved faster and most of the major PV developments in emerging PV markets were coming from utility-scale PV. This evolution had 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, 2017 (and 2018 already) 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 20 USD/MWh have contributed to the increase of the utility-scale market in 2017. Globally, centralized PV represented more than 60% of the market in 2017, mainly driven by China, the USA, and emerging PV markets. However distributed PV increased significantly in 2017, with more than 32 GW installed; with 14 GW from China alone. This change in the trend was expected for some years, but the set-up of the right policies was slow and complex.

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. The current ratio could not change significantly in the coming years, since the arrival of more developing countries will imply more focus on pure electricity generation rather than self-consumption driven business models. An expected decrease of the Chinese market could also impact negatively the fragile evolution towards more distributed PV systems.

FIGURE 12: SHARE OF GRID-CONNECTED PV MARKET PER REGION 2007 - 2017



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

Figure 12 illustrates the evolution of the grid-connected PV installations share per region from 2012 to 2017. 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 as a whole 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 2017, with the share of the Asia-Pacific region growing from 18% to more than 76%, whereas the European share of the PV market went down from 74% to around 7% in seven years.

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.

THE AMERICAS

The Americas represented 13 GW of installations and a total cumulative capacity of 59 GW in 2017. 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. Many other markets, such as Mexico, are promising.

CANADA

FINAL ELECTRICITY CONSUMPTION 2017	507	TWh
HABITANTS 2017	37	MILLION
AVERAGE YIELD	1 150	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	249	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	2 974	MW_{DC}
PV PENETRATION	0,64	%

As of December 31, 2017, the cumulative grid-connected PV capacity in Canada was approximately 2,97 GWDC. This represented a growth of approximately 9% over the previous year corresponding to a capacity of 249 MWDC. Approximately 97% of installed PV capacity was in Ontario with growth in this province catalyzed by the Green Energy and Green Economy Act initiated in 2009. Canada's centralized capacity (system size greater than 0,5 MWAC) consisted of 164 systems with a total capacity of approximately 2 GWDC. The country's distributed capacity (system size less than 0,5 MWAC) consisted of 35 211 systems with a total capacity of approximately 907 MWDC. Only grid-connected systems were surveyed, although off-grid systems do make up a small but negligible part of the country's capacity. Beyond Ontario, cumulative PV capacity is increasing in Alberta (42,3 MWDC), Saskatchewan (13,7 MWDC), and British Columbia (10,9 MWDC).

In terms of future outlook, Canada's PV capacity installation over the next four years will depend critically on provincial government policies to create expansion. Particularly, Ontario's major contribution to yearly capacity installation is declining as it's Feed-in-Tariff (FIT) programs end. Ontario's microFIT program for system sizes less than 10 kW ended in 2017. The FIT program, which had several project size tiers, applied to systems larger than 10 kW and had a final application period that concluded in 2016. The Large Renewable Procurement program replaced FIT for project sizes greater than 500 kWAC with the first phase operating from 2014 to 2016, and the second phase cancelled in 2016. Several PV projects which were under development during the FIT period will come online in 2018 and 2019 which, in combination with Ontario's net-metering program, may boost the installed capacity in spite of the end of FIT and microFIT. With the continued decline in PV module prices, there is of course strong growth potential in small-scale PV systems connected to local electricity distribution systems, and larger utility-scale systems connected to the transmission grid. However, an overall decline in annual installed capacity is expected over the next several years unless other provinces increase their installation rates accordingly to make up for Ontario's anticipated shortfall. Information on support policies for PV in other provinces besides Ontario can be found in Canada's National Survey Report available on the IEA PVPS website. Although Canada's federal government announced a price on carbon for the entire country, from 10 CAD per ton in 2018 to 50 CAD per ton by 2022, a federal policy supporting the PV industry is still very much needed to create growth conditions outside of Ontario.

CHILE

FINAL ELECTRICITY CONSUMPTION 2017	75	TWh
HABITANTS 2017	17,7	MILLION
AVERAGE YIELD	2 020	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	892	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	2 037	MW_{DC}
PV PENETRATION	5	%

Chile is one of the countries with the highest solar irradiation and a very low density of population which makes it a perfect location for PV development. With 892 MW installed in 2017, 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 2017, slightly more than 2 GW of PV were operational in the country, but the high yield resulted in a large PV electricity production.

THE AMERICAS / CONTINUED

The country has the particularity to be extremely long and was divided in four independent grid zones. The two largest grid zones where connected only during the last months of 2017. The northern grid which hosts a very large part of PV installations started to be constrained by PV development: this connection with the central grid allows for more PV plants development in the north. PV plants installed in the Central zone represent only 12% of the 2 GW installed capacity, most of them with 3 MW or less with exception of 103 MW Quilapilún PV plant and 34 MW Doña Carmen Solar PV plant.

With almost 3 000 kWh/kWp, the yield of PV installations in Chile is amongst the highest in the world and allows for reaching extremely low electricity prices. These low prices have accelerated PV market development since developers can sell PV electricity on the electricity market or conclude long term PPAs with heavy electricity consumers.

Tenders have also been implemented and allow to obtain long-term contracts for solar and wind projects. In 2016, a large tender for all energies was designed to provide 12 TWh of electricity per year, but solar was granted only 720 GWh. The winning bid for PV was at 29,1 USD/MWh for a project expected to enter into operation in 2021, one of the lowest bids ever registered until then. In 2017, new tender for all energies was designed to provide an additional 2 TWh of electricity per year starting operations in 2022. This time the share of PV increased to 900 GWh. The lowest winning PV proposal went down to 25,4 USD/MWh.

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 are being discussed since that threshold will most probably reached before the target.

Even though, most of the solar PV 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. Only 13 MW of solar PV rooftop installations were at the end of 2017.

MEXICO

FINAL ELECTRICITY CONSUMPTION 2017	287	TWh
HABITANTS 2017	128	MILLION
AVERAGE YIELD	1 780	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	285	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	674	MW_{DC}
PV PENETRATION	0,4	%

Around 285 MW of PV systems were installed in Mexico in 2017, increasing the total capacity in the country to 674 MW. While most of them were rooftop PV systems installed under the net-metering scheme until 2015, utility-scale started to grow slowly in 2016 and accelerated in 2017. To date, the many tenders granted in the utility-scale segment have not yet developed as expected but the installation numbers are growing and 2018 should see a GW market appearing on the global PV map.

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

Thus, based on the legal framework, the Energy Ministry (Secretaria de Energía, SENER) has carried out three tenders in Mexico, from 2015 to 2017. The last one reached record low levels for the PPA, down to 0,02 USD/kWh, one of the lowest in the world. The 2017 tender aimed at building nine new PV power plants, for 1,3 GW while the cumulative capacity from the two previous ones amounted to 3,5 GW.

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 2017	4 015	TWh
HABITANTS 2017	326	MILLION
AVERAGE YIELD	1 450	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	10 682	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	51 638	MW_{DC}
PV PENETRATION	1,84	%

In 2017, the PV annual installed capacity in the USA decreased from 15,1 GW to 10,7 GW. Consequently, the PV cumulative capacity has reached 51,6 GW at the end of the year 2017, pushing the USA at the second rank of all countries. The majority of the 2017 installations developed in the utility-scale segment with 6,2 GW (against 10,8 GW in 2016) and are still concentrated in a small number of States such as California, North Carolina, Arizona, Nevada, Texas and New Jersey that cover roughly two-thirds of the market.

By the end of 2017, there were more than 1,6 million distributed PV systems interconnected across the United States. Distributed PV represented 4,5 GW in 2017, a stable number compared to 2016.

Community or shared solar projects, a process in which groups of individuals either jointly own, or jointly purchase electricity from large centralized PV arrays are also growing rapidly in parts the U.S. At the end of 2017, U.S. community solar projects had a cumulative capacity of 856 MWDC. The ownership structures of community solar projects can vary widely, and have been implemented by utilities, developers, and other organizations.

As in recent years, net-metering (with specifics) remains the most widespread support measure for distributed PV and it is present in 38 states plus the District of Columbia and Puerto Rico. Five other states are transitioning to new measures. 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 permitted. Six states have feed-in tariffs for residential PV applications and seven for commercial-industrial applications. Some states are using net-billing instead of net-metering. 17 states have virtual net-metering for community solar policies.

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 the State of Hawaii where there has been registered an increase in smart water heaters, battery storage systems, and other load controls, which have started to be coupled with PV installations.

Several electricity utilities have begun engaging with PV development, either through direct ownership of centralized and distributed PV assets, community solar programs, partial ownership in PV development companies, or joint marketing agreements. In 2017, North Carolina passed a bill allowing investor-owned utilities to lease PV systems to their customers.

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 (from 30% today) 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. In addition to that one, 13 states offer personal tax credits for solar projects.

As of end of 2017, 29 states and Washington DC had RPS policies with specific solar or customer-sited provisions.

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. From 2016, loans 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.

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.

THE AMERICAS / CONTINUED

OTHER COUNTRIES

Several countries in Central and South America have continued developing in 2017.

Brazil, by far the largest country on the continent, finished the year 2017 with 1,1 GW of PV installed capacity, with 935 MW of utility-scale plants coming from the past tenders and 164 MW of distributed PV (up to 5 MW, which is a significantly higher limit that the one used on this report). Most of this capacity has been installed in 2017, with 910 MW of utility-scale projects coming online. Brazil has started to include PV in auctions for new power plants which started in 2014. Most plants installed in 2017 were coming from the 2014 and 2015 auctions. In addition, Brazil has now a net-metering system in place which starts to show some results. 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. Tax exemptions exist in several states, and solar equipment has been excluded from import duties.

In other countries, such as Argentina, the development has been quite small, with only a few MW installed in the country in 2017. 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 2017 tenders were cancelled and moved to 2018.

The PV market in Honduras has experienced a boom during 2015 with 388 MW installed, followed by 45 MW in 2016 and a few MW in 2017. 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.

In Colombia, 2018 saw the start of the building of a 82 MW plant and more is done for rural electrification. While rather low compared to other countries, the 2022 objectives of the government for renewables is set at 1 500 MW, starting from a low 50 MW at the beginning of 2017.

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 2017 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 74 GW in 2017 and more than 220 GW are producing PV electricity. This region again experienced a booming year with 45% as the region annual growth rate.

AUSTRALIA

FINAL ELECTRICITY CONSUMPTION 2017	259	TWh
HABITANTS 2017	24,1	MILLION
AVERAGE YIELD	1 400	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	1 309	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	7 470	MW_{DC}
PV PENETRATION	3,9	%

After having installed 811 MW in 2013, 862 MW in 2014, and 1 022 MW in 2015, the Australian market dropped to 866 MW in 2016 but rebounded to 1 309 MW in 2017 (without counting off-grid systems). The country has more than 7,47 GW of PV systems installed and commissioned (counting known off-grid systems until end of 2016), mainly in the residential rooftops segment (more than 1,8 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 2017, the Australian market was underpinned by the residential segment that grew by 45% to reach 779 MW. The small-commercial (10-100 kW) segment grew by 60% to reach a record 331 MW. The large commercial and industrial sized systems in the 100-5 000 kW range grew by 123% to a record 76 MW. 114 MW of solar farms were commissioned in 2017, though a far greater volume were under construction at the end of 2017. PV contributed to close to 4% of the total electricity consumption in 2017. Off-grid cumulative capacity at the end of 2016 amounted to close to 210 MW and continued to grow in 2017, but final numbers are not known yet.

Market Drivers

Australian Government support programmes impacted significantly on the PV market in recent years. The Renewable Energy Target (RET) consists of two parts – the Large-scale Renewable Energy Target (LRET), of 33 000 GWh by 2020, and the Small-scale Renewable Energy Scheme (SRES), with no set amount. Liable entities need to meet obligations under both the SRES (small-scale PV up to 100 kW, certificates granted for 14 years' worth of production) and LRET by acquiring and surrendering renewable energy certificates created from both large and small-scale renewable energy technologies.

Premium feed-in tariffs, which once acted to accelerate the deployment of residential PV, are no longer available for new connections in all but one state. Though legacy feed-in tariffs continue to apply, hundreds of thousands of customers had their historical feed-in tariff revert to unsubsidised level at the beginning of 2017.

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.

The interest in on-site storage technologies has continued to increase with at least 20 000 installations of grid-connected batteries combined with PV systems totalling 190 MWh in 2017, in addition to what is currently the world's largest Lithium-ion battery, the 100 MW / 129 MWh Tesla Hornsdale Power Reserve.

CHINA

FINAL ELECTRICITY CONSUMPTION 2017	6 037	TWh
HABITANTS 2017	1 390	MILLION
AVERAGE YIELD	1 300	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	53 068	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	131 141	MW_{DC}
PV PENETRATION	1,8	%

With 53,1 GW installed in 2017, the Chinese PV market has once again experienced a significant growth rate, a year-on-year increase of close to 54%. With these installations, Chinese PV capacity confirmed its first rank with more than 131 GW at the end of 2017. 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 33,6 GW installed in 2017. From 2013 until 2016, this segment contributed for a large part of all installations. In 2017, for the first time, the newly installed capacity of solar PV power generation exceeded the newly installed capacity of thermal power, becoming the largest installed capacity, accounting for 40% of the newly installed power capacity of the year, 2,7 times that of the newly installed wind power. Distributed PV capacity added in 2017 amounted to around 20 GW, a record-high number, including floating and agricultural PV (close to 6 GW together).

Several schemes are incentivizing the development of PV in China. They aim at developing different segments through adequate schemes: utility-scale PV, rooftop PV in city areas and micro-grids together with off-grid applications in the last unelectrified areas of the country. The following regulations were in place in 2017:

- In July 2017, the National Energy Administration issued a new document aiming at guiding renewable energy development during the 'Thirteenth Five-year Plan' period. This document aims at framing how renewable energies and PV have to be framed in the coming years.
- Due to the price decrease of PV components, in December 2017, the National Development and Reform Commission issued the "Notice on 2018 PV power project price policy", which lowered the PV power benchmark price by 0,10 CNY/KWh in three types of electric price regions to the levels of 0,55 CNY/KWh, 0,65 CNY/KWh and 0,75 CNY/KWh respectively.
- The PV Poverty alleviation program allows to develop PV on roofs in seven provinces and cities with no scale limitation in order to fight poverty. 15 GW of PV will be installed before 2020 for poverty alleviation.
- Since 2016, China started to explore competitive method to reduce the costs of renewable energy projects. The deployed competitive projects represented by the so-called "front runner" program are meant to accelerate the competitiveness of PV plants. In March 2018, China completed the bidding for 7 PV "front runner" plants in the third batch of projects.
- In the second half year of 2017, driven by the "front runner" program, a number of new technologies and processing have been applied to allow higher-efficiency cells and modules to massively develop.

China was the first PV market in the world for the fifth year in a row in 2017. This development of PV in China is driven by the NEA's "Guiding Opinions on the Implementation of the 13th Five-Year Plan for Renewable Energy Development" which defines a target of 60 TWh of distributed PV electricity by 2020, out of 210 TWh of PV electricity in total (but more should be achieved, possibly up to 250 TWh). According to the statistics of the NEA, PV contributed to 1,87% of the total electricity consumption.

JAPAN

FINAL ELECTRICITY CONSUMPTION 2017	906	TWh
HABITANTS 2017	127	MILLION
AVERAGE YIELD	1 050	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	7 459	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	49 500	MW_{DC}
PV PENETRATION	5,1	%

In 2017, Japan installed 7,5 GW of new PV capacity, a similar level to that of 2016. The country has reached a total installed PV capacity of 49,5 GW, making it the third country in the world after China and USA. Currently, the majority of the capacities installed are grid-connected installations, while off-grid remains marginal. After having reached close to 11 GW in 2015, the market stabilized at a lower level in 2017 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 Japan rapidly to one of the top countries in the global PV market. While Japan was one of the first markets in the world in the first decade of this century, most installations took place after the implementation of the FiT program.

ASIA PACIFIC / CONTINUED

While the PV market in Japan developed in the traditional residential rooftop market, 2017 has seen again a major deployment of utility-scale plants: such systems represented 2,95 GW in 2017. The residential market reached 646 MW in 2017, followed by the commercial segment with more than 2 GW and the industrial segment with close to 1,2 GW. BIPV installations represented 35 MW and off-grid applications 9,4 MW.

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 for 20 years for systems between 10 kW and 2 MW, and 10 years for the excess electricity of PV systems below 10 kW. From April 2017, a tendering scheme started for PV plants (2 MW and above) under the Fit Scheme. 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 market seen in last years.

In 2017, 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.

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 charges. Self-consumption can benefit from subsidies in the commercial segment.

From the fiscal year 2017, a preferential tax treatment (under the Act for Facilitating New Business Activities of Small and Medium-sized Enterprises) was initiated. It offers immediate depreciation and reduction of fixed property tax for PV systems used for self-consumption (the excess electricity is sold).

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 35 MW were installed in 2017. However, Japan is preparing the uptake 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

Distributed energy storage using batteries was included in the subsidies for installations of net zero energy houses (ZEH) and demonstration projects of net zero energy building (ZEB). Some local governments also support storage batteries. For example, the Tokyo Metropolitan Government (TMG) has been conducting the "Project to expand introduction of renewable energy for local production and local consumption" . The program of "Subsidy for project expenses to establish virtual power plants" supports demonstration projects for establishment of business models in which energy facilities such as storage batteries are used and efforts towards demand response with high level of control.

As for grid-storages, demonstration projects to install storage batteries were underway throughout 2017. Demonstration projects are also conducted for hydrogen storage. Some PV power plants mainly installed in Hokkaido area, utility scale storage batteries were installed to meet grid connection contract with utility companies.

Conclusion

The former second market for PV reached a high level in 2015 and has stabilized in 2017, making Japan the fourth ranked country. The market will see a soft landing in the coming years with more than 30 GW of approved projects under the FIT program still to be developed. 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 5,1% of the total electricity consumption in 2017 and will be able to cover at least 5,5% in 2018 based on the already installed capacity.

KOREA

FINAL ELECTRICITY CONSUMPTION 2017	508	TWh
HABITANTS 2017	52	MILLION
AVERAGE YIELD	1 314	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	1 370	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	5 873	MW_{DC}
PV PENETRATION	1,4	%

Since "The Renewable Portfolio Standards" (RPS) replaced the Korean FiT at the end of 2011, the Korean PV market followed an upward trend that stabilized around the GW mark: The country installed 1,37 GW in 2017, after having installed 887 MW in 2016.

Utility-scale PV plants accounted for around 1,25 GW of the installed capacity in 2017. Distributed PV systems amounted to around 11,4% 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. At the end of 2017, the total installed capacity reached 5,9 GW. PV contributed to 1,4% of the total electricity consumption 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.

In December 2017, the new Moon's government announced so-called "RE3020 plan," which aims at supplying 20% of the electricity generation by renewable sources by 2030. With this plan, Korea plans to install 36,5 GW (cumulative) PV systems by 2030. A two-track approach will be taken, which aims at deploying small-scale PV systems for individual households and cooperative unions in one track, and large-scale PV systems for agricultural sites and pre-planned sites (e.g. reclaimed area) on another track.

RPS Programme

The RPS is a mandated requirement that the electricity utility enterprises source a portion of their electricity supplies from renewable energy. In Korea, electricity utility business companies (total 18 power producing companies) exceeding 500 MW in capacity 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.

Korean-type FiT

To improve the bankability of small-scale distributed PV system installations, a new temporary (for the period of 2018-2022) subsidy measure will be introduced in 2018: A fixed contract price of 189 175 KRW (for 20 years) will be provided for systems less than 30 kW with no restriction, and for systems less than 100 kW if they are run by farmers, fishermen or Co-ops.

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 2017.

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.

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.

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 70 000 KRW/month which is on the average less than 80% of the electricity bill) for a minimum of seven 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.

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.

MALAYSIA

FINAL ELECTRICITY CONSUMPTION 2017	140	TWh
HABITANTS 2017	32	MILLION
AVERAGE YIELD	1 413	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	60	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	401	MW_{DC}
PV PENETRATION	0,4	%

The Malaysian market remains small compared to some key markets in Asia but implements policies that should pave the way to renewable energy development. In 2017, the newly installed

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PV capacity amounted to 60 MW. The cumulative installed capacity in Malaysia topped 401,6 MW at the end of 2017. A total of 11 913 applications for PV under the FiT were approved with a total capacity of 440 MW. The breakdown of approved applications is as follows: residential (10 747 applications 98,6 MW), communities (478 applications amounting to 11,6 MW), and other applications (688 applications or 330,2 MW). As of 31 December 2017, a cumulative installed capacity of 354,03 MW of PV projects under the FiT programme were operational. The remaining PV capacity came from net-metering, self-consumption, off-grid and utility-scale PV plants.

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 responsibility to implement and manage the FiT mechanism. The FiT programme is financed by a Renewable Energy Fund (RE Fund) funded by the electricity consumers via a 1,6% levy added to the consumers' monthly electricity bills. Domestic consumers with a consumption below 300 kWh per month are exempted to contribute to the fund. Due to the limited amount of the RE Fund, the FiT is designed with a cap for each technology.

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 scheme is defined at 500 MW over a period of five years. The scheme was active in 2017 but contributed marginally to market development.

Despites the potential of PV, its development is still rather small in Malaysia, Peninsular and even more in Sarawak or Sabah. However, Malaysia is becoming a major hub for PV manufacturing, with several GW-scale manufacturing plants producing.This was achieved thanks to a voluntary commitment from the government that set up the right policy framework to attract foreign companies. The stability of the country did the rest.

THAILAND

FINAL ELECTRICITY CONSUMPTION 2017	194	TWh
HABITANTS 2017	69	MILLION
AVERAGE YIELD	1 522	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	251	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	2 698	MW_{DC}
PV PENETRATION	2,1	%

The PV market increased significantly in Thailand with 251 MW that have been installed in 2017, down from the GW installed in 2016. The large majority of installations developed in 2017 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 2017, the cumulative grid-connected PV capacity reached close to 2,7 GW and 34 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 2017. Until April 2016, 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 2016 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 were 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. At the end of the pilot phase in June 2017, 180 projects amounted to 5,6 MW of PV installations.

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.

OTHER COUNTRIES

2017 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.

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 around 5 million SHS in the beginning of 2018 (representing more than 250 MW). 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: 3 MW of utility-scale PV was operational begin of 2018 and 800 MW more had been approved. The country targets 3,2 GW of renewables by 2021, out of which 1,7 GW of PV. In total, more than 500 MW were operational begin of 2018. The government is targeting to add 2 GW of renewable energy capacity under the 7th 5-year plan from 2016 to 2020.

India, with more than one billion inhabitants has been experiencing severe electricity shortages for years. The Indian market jumped to 9,1 GW in 2017 from 779 MW in 2014, 2 GW in 2015 and 4,1 GW in 2016, 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 initially aimed at installing 20 GW of grid-connected PV systems by 2022 and an additional 2 GW of off-grid systems, including 20 million solar lights. This level has been reached already in 2018. 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 to meet the official ambitions. However, hurdles remain and will most probably impact the PV market in the coming years. 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. Its current goal is to install 1 000 GW in its member (emerging) countries by 2030. Introduction of PV in India has been mostly driven by auction and with the growth of the market, PPA prices have been very competitive. India's safeguard measures should impact the market.

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. In 2017 a new law redefined the conditions to get the FiT and pushed the state utility to conclude PPAs for renewable energies, which could trigger some accelerated market development. However, following order issued in February 2018 has allowed to negotiate FiT tariff level with IPPs, independent power producers. Thus, FiT programme did not seems effective to catalyze the full-scale growth of the PV market. Indonesia has the target to procure 23% of its energy mix from renewable sources by 2025.

In 2017, Taiwan installed about 515 MW mostly as grid-connected rooftop installations after having installed 369 MW in 2016, 227 MW in 2015 and 223 MW in 2014. The total installed capacity at end of 2017 is estimated to be around 1,7 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. It is notable that the FiT level is higher for floating PV and the projects employing high efficiency PV modules. 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 6,5 GW by 2020 and 20 GW by 2025. 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.

Pakistan is reported to have installed close to 1 GW in 2017. A FiT has been introduced for utility-scale PV in 2014. It is estimated that at least 500 MW have been installed so far. The FiT exists for plants between 1 and 20 MW, 20 and 50 MW and 50 to 100 MW. It is granted during 25 years and its value is established around 10-11 USDcents per kWh. Since 2015, a net-metering system exists for projects below 1 MW. The government has published a target of 9,7 GW of renewables by 2030. At the beginning of 2018, 25 projects representing close to 1 GW were at different development stages. Six projects totalling 430 MW were operational mid 2018. 13 additional projects for 421 MW were under development by mid-2018 with COD in 2018/2019. In addition, 3,3 GW of projects have been initiated at provincial level. Net-metering exists in Punjab since 2018.

ASIA PACIFIC / CONTINUED

The Philippines have installed around 70 MW in 2017, raising the total installed capacity to 995 MW and much more is foreseen in the coming years. 887 MW were utility-scale plants while distributed PV represented only slightly more than 100 MW. As of the beginning of 2017, there were 124 grid-connected projects in the pipeline that had been awarded under the country's renewable energy (RE) law, totalling 4 GW. Meanwhile, little was installed during the year 2017 after the government set the due date for the FIT program and created a rush of installations in 2016.

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 decreased while there has been rapid growth in the rest of the world. Europe accounted for only 7% of the global PV market with 6,1 GW in 2017. European countries had 110 GW of cumulative PV capacity by the end of 2017, the second largest capacity globally after having been on the top for years. 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.

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 exit the agreement and to enter the European PV market by paying the anti-dumping charges. In September 2018, the end of the tariffs was decided, opening the EU market to lower costs modules.

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.

New Targets

A political agreement on increasing renewable energy use in the European Union was reached among the Commission's negotiators, the European Parliament and the Council on 14 June 2018. The agreement sets a new, binding, renewable energy target for the EU for 2030 of 32%, including a review clause by 2023 for an upward revision of the EU level target. To realise the new renewable energy target of 32% by 2030, the European Union has to increase its use of renewable energy in the power sector to at least 65%. The main contributions have to come from solar and wind power.

Due to different energy policies, regulations and public support programmes for renewable energies in the various countries, market conditions for PV differ substantially. Besides these policy-driven factors the varying grades of liberalisation in the domestic electricity markets as well as the maturity of the PV market and local financing conditions has a significant influence on the economic attractiveness of installing PV systems.

Looking at the electricity system as a whole, a total of about 28,1 GW of new power generation capacity were installed in the EU in 2017 and 12,1 GW were decommissioned, resulting in 15 GW of new net capacity. Renewable energy sources (RES) accounted for 23,7 GW or 84,5% of all new power generation capacity.

In terms of new net capacity, wind power was first with 15 GW, followed by solar PV 5,9 GW, hydro 1,1 GW biomass plants with 0,96 GW, natural gas 356 MW, CSP 118 MW and other sources 8 MW. The net installation capacity for coal- and oil-fired power plants as well as nuclear was negative, with a decrease of 4 GW, 2,2 GW and 1,3 GW, respectively.

Since 2005, solar PV electricity generation capacity has increased from 1,9 GW to 108 GW at the end of 2017. Already in 2014, the 2020 National Renewable Energy Action Plan (NREAP) target of 83,7 GW was exceeded, reaching about 88,4 GW.

With a cumulative installed capacity of 108 GW, the EU has further lost ground in the worldwide market, representing now only 27% of the global total of 401 GW of solar PV electricity generation capacity at the end of 2017. This is a steep decline from the 66% recorded at the end of 2012.

The installed PV power capacity in the EU at the end of 2017 can generate around 120 TWh of electricity or about 4,5% of the final electricity demand in the Union.

At first glance, this development appears to be a success. However, by looking at the annual installations, it becomes obvious that between 2011 and 2017 Europe's share was not only declining in relation to a growing market worldwide, but also in actual installation figures.

What happened to the most dynamic PV zone in the world until 2012? Some Member States had introduced support schemes which were not designed to react fast enough to the very rapidly growing market and this led to unsustainable local market growth rates. To counteract this, unpredictable and frequent changes in the support schemes, as well as legal requirements, led to installation peaks before the announced deadlines and high uncertainty for potential investors. A number of retroactive changes have further decreased investment confidence, which consequently resulted in the declining PV system market in the EU.

AUSTRIA

FINAL ELECTRICITY CONSUMPTION 2017	71	TWh
HABITANTS 2017	9	MILLION
AVERAGE YIELD	1 050	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	173	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	1 271	MW_{DC}
PV PENETRATION	2,16	%

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 four years. With around 173 MWdc

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installed in 2017, 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 5 MW in 2017. Off-grid development amounted to less than 1 MW. Off-grid contribute in total for around 6 MW out of 1,3 GW as Austria cumulative market end of 2017.

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 2017	82	TWh
HABITANTS 2017	11	MILLION
AVERAGE YIELD	962	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	892	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	3 877	MW_{DC}
PV PENETRATION	4,3	%

Belgium is a complex case with different PV incentives in the three regions that compose the country, but one single 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 2,8 GW of PV systems. In Wallonia, the market started with a two-year delay and remains largely concentrated in the residential and small commercial segments with around 1 GW at the end of 2017. In Flanders, large rooftops and commercial applications have developed since 2009. 289 MW were installed in the country in 2017, which represents a strong increase in comparison with the 200 MW installed in 2016. Belgium now runs 3,9 GW of installed PV systems.

For small rooftop installations below 10 kW (or 5 kW for Brussels), 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 paid annually) was introduced in July 2015 for all small PV systems (below 10 kW). Despite this, the market has remained quite active so far. 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 of around seven years for a new PV installation. This success is mainly due to the intensive 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 in your bank account," along with comprehensive tools such as a solar map that shows the potential of each roof.

In Wallonia, the "Qualiwatt" support plan for small systems (≤ 10 kW) introduced in 2014 has had a mitigated success in 2017. It improved in comparison with 2016 but the maximum allowed quota for installations was not reached (~8 400 out of 12 000). The Qualiwatt program is an up-front incentive paid over five years that is calculated to yield a payback time of 8 years (5% IRR for a 3 kWp 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. In any case, the climate for PV remains negative due to 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 2020, 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. 2017 was a good year for large systems in Wallonia. 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 2017.

The Belgian market is evolving from an incentive-driven market to a self-consumption-driven market. This transition will imply a revision of the net-metering policies and possibly of other new forms of incentives in the coming years. It is noticed that there is a strong political will to continue to develop the PV market confirmed by the quite ambitious target for 2030: the translation of the new European Renewable Energy Directive into regional plans gives an annual target of more than 550 MW in order to reach 11 GW.

DENMARK

FINAL ELECTRICITY CONSUMPTION 2017	31	TWh
HABITANTS 2017	6	MILLION
AVERAGE YIELD	950	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	61	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	910	MW_{DC}
PV PENETRATION	2,5	%

60,7 MW of PV systems were installed in Denmark in 2017, with 24,2 MW in the distributed segment and 36 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 0,5 MW installed in 2017. In total, 910 MW of PV were producing electricity in the country at the end of 2017.

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 this 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 was 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.

A new energy plan coming into play from 2020 and onwards has been under preparation for some time. The national energy committee that set it up has recommended renewable energy to be deployed based on market conditions (technology neutral auction schemes instead of politically defined technology targets), an effective international energy markets to be promoted and an integrated and flexible energy system including all technologies to be developed. The new energy plan was finally decided in mid-2018.

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.

FINLAND

FINAL ELECTRICITY CONSUMPTION 2017	86	TWh
HABITANTS 2017	6	MILLION
AVERAGE YIELD	875	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	43	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	80,4	MW_{DC}
PV PENETRATION	0,08	%

The total capacity of grid-connected PV plants is estimated at around 69,8 MW. However, the market in 2017 witnessed visible signs that the segment of grid-connected rooftop PV systems is starting to grow for residential and commercial buildings with 43 MW installed. There has been no utility-scale PV plants in Finland so far. The off-grid PV market in Finland started in the 1980s and has focussed 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. With 43 MW of new grid-connected PV capacity installed in 2017, the cost of all PV support measures was approximately 10 MEUR. The decision for the investment subsidy is made case-by-case based on application. 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

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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 2017	482	TWh
HABITANTS 2017	67	MILLION
AVERAGE YIELD	1 160	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	875	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	8 076	MW_{DC}
PV PENETRATION	1,9	%

France launched its Climate Plan in 2017, targeting carbon-neutrality for 2050, and counts on photovoltaics to contribute 18,2 to 20,2 GW of capacity by 2023 in its Multiannual Energy Plan (MEP). In December, as a lengthy consultation process with industry actors to revise the mainland MEP came to an end, amid the realisation that current MEP targets would not be met, an additional 1 GW of capacity was added for future Tenders up to 2019. In parallel, the country's dominant energy supplier, EDF, announced it would install 30 GW in France before 2035. Separate regional MEP were published for overseas territories.

New capacity installed in 2017 in France reflected the French government's commitment to supporting the most cost competitive PV plants: over 50% of the 875 MW new capacity (up from 559 MW in 2016) was composed of utility-scale installations, installed within the framework of competitive tenders, while only 10% of new capacity was for residential systems. National cumulative capacity has hit 8,08 GW, and if over 90% of all systems are residential systems, this represents a low 15% of total capacity.

Commercial, industrial and utility-scale projects over 100 kW continue to be tendered; in that respect, 11 competitive tenders were called in 2017, for a combined capacity of 2,16 GW, of which more than ¾ was for systems over 500 kW. The costs of large and utility-scale projects have once again been reduced as they compete in these tenders, but remain higher than in other countries, in Germany for instance. The carbon footprint and land usage bonus within tenders have remained in place, as has the popular citizen investment bonus of 3 EUR/MWh.

Whilst most capacity was installed within large systems, self-consumption has taken over much of the market for residential systems and been a focal point for sector events involving industry stakeholders, the energy regulator and the government. This move to self-consumption has been pushed by several targeted measures. However, low market electricity costs have meant that this move to self-consumption has been mostly restricted to very small or experimental and flagship systems. Typical system costs remain relatively high compared to neighboring markets for residential systems, ranging from 1,9 EUR/W to 2,6 EUR/W.

A new Feed-in Tariff regulation for systems under 100 kW was published in May 2017 and ended the all-BIPV support schemes for small systems, although eligible systems must still be on buildings. The new terms include a lump sum bonus combined with net-billing tariffs for systems under self-consumption. A separate regulation with regional tariffs for overseas territories was also published. As previously, feed-in tariff levels are segmented according to system size.

The much awaited regulatory and administrative framework for collective self-consumption and virtual metering was published, although the complexities meant that only a handful of projects were ready for commissioning in 2017. Indirect support for self-consumption systems under 1 MW was available with tax and surcharge exemptions representing up to 30% of a consumer's electricity bill for self-consumed electricity.

Upfront grid connection costs were reduced by up to 40% for systems under 5 MW, a significant incentive in the small to medium segment where standard grid connection costs could represent 20% of system costs.

Feed-in tariffs, feed-in premiums and lump sum incentives are funded through the Electricity as a Public Service Charge (CSPE), that is financed by electricity consumers through a surcharge on electricity consumption fixed at 22,5 EUR/MWh in 2017. For residential consumers in France, support for photovoltaics represents approximately 5% of the cost of kWh consumption in 2017.

GERMANY

FINAL ELECTRICITY CONSUMPTION 2017	541	TWh
HABITANTS 2017	83	MILLION
AVERAGE YIELD	960	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	1 776	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	42 491	MW_{DC}
PV PENETRATION	7,6	%

With installations close to 1,8 GW in 2017, Germany was ranked sixth of the largest global PV markets. Since 2014, yearly installations are constantly increasing from 1,2 GW (2014) to 1,8 GW (2017) with an ongoing positive trend in 2018. The German PV market is a GW market since more than 10 years having installed a total cumulative capacity of 42,5 GW by the end of 2017. Given the average yield and the capacity of the PV systems installed by the end of 2017, a share of 7,6% of the electricity demand could be covered by PV, while with respect to the overall electricity production in 2017, the contribution of PV reached 6,8% of the electricity mix. This was achieved thanks to a combination of several elements, especially a long term stability of support schemes, the confidence of investors, and the appetite of residential, commercial and industrial building owners for PV.

Breathing Feed-in Tariff

The EEG law (Renewable Energy Sources Act) has introduced the FiT concept in 2000 and has continued to promote it while adapting the details to the current market situation. It introduces a FiT for PV electricity that is mutualized in the electricity bill of electricity consumers.

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 annual threshold was set to 2,5 GW: 1,9 GW BAPV/BIPV + 0,6 GW ground mounted. In that respect, the FiT was reduced during 2017 by approximately 0,8% (Example for small rooftop systems <10 kWp: 0,123 EUR/kWh (01.01.2017) to 0,122 EUR/kWh (31.12.2017)). This trend will continue in 2018: A reduction of at least 3% is already confirmed based on 1,3 GW installed in the first half of the year.

With large systems approaching parity, the FiT concentrated on funding smaller systems. Since 2017 systems below 100 kWp can benefit from the classic FiT (fixed tariff), 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. In 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 pay 40% of the surcharge for renewable electricity for the self-consumed electricity for systems above 10 kW. In 2017 this surcharge amounted to 0,0688 EUR for every kWh consumed from the grid (in 2018: 0,06792 EUR).

A program of incentives for storage units was introduced 2013, which aims at increasing self-consumption and developing PV with battery storage in Germany. A 25 MEUR market stimulation program 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 program around 20 000 decentralized local storage systems were funded by the end of 2016. During 2017, 6 954 storage systems were funded, of which 6 390 were part of a new PV system and 564 being an upgrade for existing systems. The total funding within those two measures amounted to 223 MEUR. A continuation of those programs is planned. However the number of installed battery storage system is higher: it is estimated that 20 000 have been installed in 2017 and the 100 000 mark has been reached in August 2018.

Market Integration Model

While the measures described above target small systems, Germany promotes the marketing of PV electricity on the spot market by offering a "market premium" on top of the price obtained for a kWh on the spot market. For new PV installations above 100 kWp and up to 750 kWp this model is mandatory, while owners of smaller systems can switch between the fixed FIT and the market premium model. The market premium is changed depending on the market level similarly to the classic fixed FiT.

Tenders

Ground mounted systems and systems >750 kWp have to run through a tendering procedure. Three calls with a total capacity of 600 MW are executed every year. The price level of the successful bids declined from call to call. Starting from 0,0917 EUR/kWh in the pilot auction 2015, the average price of the successful bids in the auction from October 2017 was 0,0491 EUR/kWh (Range: 0,0429 EUR\kWh to 0,0506 EUR\kWh).

The commissioning deadline for the projects is two years, the implementation rate for the 2015 auctions is above 90%.

2018 auctions continue the trend of decreasing prices. The parties of the newly installed government agreed within their coalition agreement to execute tenders for 2 GW in addition to the continuous programs.

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, for systems below 30 kW which are not remotely controlled by the grid operator.

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ITALY

FINAL ELECTRICITY CONSUMPTION 2017	302	TWh
HABITANTS 2017	61	MILLION
AVERAGE YIELD	1 251	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	400	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	19 682	MW_{DC}
PV PENETRATION	8,1	%

At the end of 2017 more than 774 000 plants were installed in Italy for a total capacity of 19 682 MW. The Italian market was quite stable with a new capacity of 414 MW (400 MW when including decomissionned off-grid systems) and about 44 000 PV plants installed in 2017. PV electricity production reached 24,4 TWh in 2017, a growth of 10% compared to the previous year.

Around 80% of the all PV systems installed in 2017 were residential, while half of the total capacity were related to industrial applications, with several plants with capacity between 200 kW and 1 MW. The public administration owns 16 073 PV plants for a capacity of 748 MW (3,8% of the installed capacity in Italy). As a matter of fact, around 66% of the Italian municipalities have at least one PV plant owned by the public administration.

Electricity produced by PV and self-consumed amounted to 4,9 TWh in 2017, around 20% of total PV systems production, with a slight increase compared to 2016.

The cumulative installed capacity is mostly due to past incentive mechanisms, from the so-called "10 000 PV Roofs" of early 2000 to the five decrees of 2005 – 2013 (from Feed-in Premium to Feed-in Tariff, all named "Conto Energia"). The cost of the incentives is covered by a component of the electricity tariff paid by all final electricity consumers; for high energy intensive industry there are reductions or exemptions. The financial cap set by the FiP/FiT law was 6,7 BEUR in terms of yearly payments.

After the end of the FiT law in 2013, tax credit (available for small size plants up to 20 kW and for storage devices), together with a net-billing scheme (so-called Scambio Sul Posto - SSP), are the measures to support the PV market that exists now. Italy switched from the net-metering mechanism to a net-billing scheme for systems below 500 kW in 2009, 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). The net-billing scheme is valid for one year and automatically renewed once granted. Market prices are applied for the electricity injected into the grid as an alternative to SSP. Self-consumption is allowed for all PV system sizes.

NETHERLANDS

FINAL ELECTRICITY CONSUMPTION 2017	114	TWh
HABITANTS 2017	17	MILLION
AVERAGE YIELD	950	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	853	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	2 938	MW_{DC}
PV PENETRATION	2,5	%

2017 was a successful year for the Dutch PV market that grew up to 853 MW, the highest level ever. This pushed the total PV installed capacity to close to 2,94 GW, mostly in the residential PV market. The total generated solar electricity was 2,15 TWh or 1,85% of the net electricity generation.

Until 2003, the Dutch PV market developed thanks to an investment grant that was extremely successful but the market collapsed after this. 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 5 000 kWh. This triggered an important market development which lasts till now. There is a consensus amongst policymakers to maintain the net-metering system until 2020.

Systems larger than 15 kW can apply for the programme to stimulate sustainable energy production (SED+), for a maximum of 950 full load hours per year, which is open for all renewable energy technologies. Over 3 700 PV projects with a combined capacity of 1,7 GW were selected in the first round of the 2018 SDE+. This brings the total approved capacity of PV systems for both years; 2017 and the first 2018 allocations to 5,9 GW. This system can be called "reverse auctioning system".

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 concepts 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 2017	132	TWh
HABITANTS 2017	5	MILLION
AVERAGE YIELD	800	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	17	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	45	MW_{DC}
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 and commercial systems especially in 2016. In 2017, the grid-connected segment dominated the market completely with 17 MW installed: installations were split between commercial (14 MW) and residential (3 MW) installations.

Overall, the total installed capacity reached 45 MW at the end of 2017. That market growth was achieved despite weak incentives and low electricity-prices due to hydropower.

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 backup 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. Commercial applications developed significantly faster in 2017.

Since 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 2017	51	TWh
HABITANTS 2017	10	MILLION
AVERAGE YIELD	1 600	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	64	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	2 581	MW_{DC}
PV PENETRATION	1,3	%

The Portuguese PV market reached 64 MW in 2017, registering a small increase with respect to the previous yearly level of installations (52 MW). The industrial segment was again the largest with 28 MW installed, while the other distributed grid-connected segments reached only 4 MW together. This can be explained by the growth of off-grid residential and commercial installations that reached 20 MW in 2017. These off-grid installations shouldn't be understood as traditional off-grid but rather PV installations on normal buildings which are not injecting into the grid to avoid punitive regulations. 12 MW of utility-scale plants were installed in Portugal in 2017. The total installed capacity reached about 584 MW end of 2017.

For more than a decade, Portugal has defined a regulatory framework that has enabled to develop a strategy for promoting renewable energies and set specific objectives for technology and in recent years has remained committed to a medium- and long-term policy. The effects of the financial crisis pushed the country to slow down its PV program some years ago: 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. In the future, Portugal intends to increase the percentage of use of renewable sources, and it is foreseeable that a greater use of photovoltaic energy will take place.

Individual self-consumption is allowed in Portugal, with the PV system allowed with a maximum capacity twice as high as the grid

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connection. Excess PV electricity is injected into the grid and remunerated at 90% of the wholesale market prices. Systems up to 1,5 kW don't receive this remuneration for excess electricity. If the PV systems is integrated in the process of of renovating the building, the owner can benefit from an investment subsidy. Collective self-consumption in buildings is allowed in theory but the regulations are quite complex, which discourage the investment.

From 2015, it was decided that the model would allow a transition from the FiT system to an electricity market based model, with remuneration based on electricity market prices. 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.

At the time of this writing, new projects are only accepted under market conditions. This means that the new PV installations (as any new renewable power plant) should bid in the wholesale energy market with no other chance of getting revenues. The Portuguese Government has already approved the installation of 968 MW (till June 2018) of PV power plants without any financial support.

SPAIN

FINAL ELECTRICITY CONSUMPTION 2017	253	TWh
HABITANTS 2017	47	MILLION
AVERAGE YIELD	1 450	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	148	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	5 331	MW_{DC}
PV PENETRATION	3,4	%

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 2017, only 148 MWdc were installed in Spain and the total installed capacity topped almost 4,9 GWac (5,3 GWdc), which can be explained by the difficult economic environment and the constraining PV policies.

In October 2018, a new regulation of PV development changed significantly the PV landscape after years of constrained development that saw the market going down to extremely low levels.

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 considered 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:

- 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 2017, geographical compensation was not allowed, and self-consumption for several end customers or a community was allowed but not regulated.

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 and self-consumption. Thanks to the renewable energy tenders organized in 2017 to meet the EU energy and climate targets and the Paris Agreement. PV was awarded with 3,9 GW of projects to be built before 1 January 2020. PV project developers are also looking into other sources of financing, such as PPAs or the wholesale electricity market for possibly GWs of PV installations in the coming years. Self-consumption developed further in 2017, adding 134 MW of on-grid and off-grid self-consumption projects.

The two key objectives supported by an important part of the civil society and policymakers to implement in the coming years are the elimination of self-consumption technical and administrative barriers and ensuring that renewable projects get a fair legal framework back. This was achieved only in October 2018 with new regulations being voted which will change the PV landscape in Spain from 2019 onwards. This will power the second age of photovoltaic solar energy in Spain.

SWEDEN

FINAL ELECTRICITY CONSUMPTION 2017	141	TWh
HABITANTS 2017	10	MILLION
AVERAGE YIELD	950	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	118	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	322	MW_{DC}
PV PENETRATION	0,2	%

PV installations increased once again in Sweden in 2017: 118 MW were installed compared to 79 MW one year before: the market grew 52% year-on-year. 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 rooftop PV systems installed by private persons or companies: annual residential installations reached 41 MW and commercial or industrial ones 67 MW. BIPV represented around 1 MW and ground-mounted systems 3 MW.

The total installed capacity reached the 322 MW mark in 2017 compared to 205 MW at the end of 2016. Of this, 294 MW were installed in the distributed grid-connected segments.

The off-grid market increased to around 2.3 MW in 2017. As in 2016, and in the same way as in many European countries, the large increase of installed systems occurred within the segment of grid-connected systems. 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 a newly introduced tax deduction system.

Incentives

A direct capital subsidy for installation of grid-connected PV systems has been active in Sweden since 2009. When it was introduced, support rates were 55% for large companies and 60% for all others. Originally, 50 MSEK was deposited annually for three years. This support program has since been extended, support levels have changed, and more money has been allocated. To meet the increased interest in PV in Sweden, the current Government decided in the autumn of 2015 to greatly increase the annual budget for the years 2016–2019 with 235, 390, 390 and 390 million, respectively. In 2017, the budget was increased even more, which means that the total support will be 1 085 MSEK for 2018, and then 915 MSEK per year for 2019 and 2020 (if not a new government after the election in the autumn 2018 changes the budget for 2019 and 2020). In 2017, the subsidy level was 30% for large companies and 20% for all others. For 2018, this was changed so that all actors now get 30% of their installation costs covered. Since its introduction, the interest in the capital subsidy program has always been greater than the budget allocated. Therefore, a long queue to get the subsidy has arisen.

Net-metering has been discussed and investigated in Sweden. However, instead of introducing net-metering the government introduced a tax deduction of 0,06 EUR per kWh in 2015 for the excess electricity fed into the grid, which PV owners with a fuse below 100 ampere are 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. The value of the tax deduction together with the remuneration from the utilities usually adds up to the same value as when the PV electricity is self-consumed.

Additionally, a tradable green certificates scheme exists since 2003. The basic principle of the green electricity certificate system is that producers of renewable electricity receive one certificate from the Government for each MWh produced. Meanwhile, certain electricity stakeholders are obliged to purchase certificates representing a specific share of the electricity they sell or use, the so-called quota obligation. The sale of certificates gives producers an extra income in addition to the revenues from electricity sales. Ultimately it is the electricity consumers that pay for the expansion of renewable electricity production as the cost of the certificates is a part of the end consumers' electricity price. The goal of the certificate system has been to increase the renewable electricity production by 28,4 TWh until 2020. In 2017, the electricity certificate system was extended to 2030 with another 18 TWh of renewable electricity. The green electricity certificate system in the present shape is being used by some larger PV systems and parks but does not provide a significant support to increase smaller PV installations in Sweden due to the complexity for micro-producer to benefit from the scheme. This has led to that only about half of the grid-connected PV capacity in Sweden are using the scheme.

The Swedish PV market is expected to continue growing with the introduction of the tax deduction for micro-producer, the increase of support 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 uphold the fast growth in upcoming years.

SWITZERLAND

FINAL ELECTRICITY CONSUMPTION 2017	58	TWh
HABITANTS 2017	9	MILLION
AVERAGE YIELD	970	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	242	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	1 907	MW_{DC}
PV PENETRATION	2,9	%

242 MW were connected to the grid in Switzerland in 2017, a 10% decrease compared to the previous year. After 2016, this is the second consecutive year that the newly installed PV capacity is declining. Limitations and uncertainties of new funding for the supporting scheme as well as reduced buy-back tariffs paid by the Distribution System Operators had a negative impact on the development of PV. With the adoption of the new energy act in May 2017 and partly improved conditions for PV development, it is expected that the added capacity in 2018 will reach again the 300 MW benchmark. In total, Switzerland hosted 1,91 GW of PV systems at the end of 2017. Their production corresponded to 2,9% of the total electricity consumption, making PV the second to hydropower in the renewable electricity portfolio.

Almost the entire PV market consists of rooftop applications and the few ground mounted PV applications are relatively small in size (the largest ground mounted PV installation in Switzerland has a size of 6 MW). The total off-grid applications market stood at level of less than 4 MW with an annual market of approximately 400 kW. In 2017, residential installations (smaller than 30 kWp DC) represented 115 MW, the commercial segment (30-100 kW DC)

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about 27 MW and the industrial one (> 100 kW DC) 100 MW. Compared to the previous years, this corresponds to a distinct market shift towards installations smaller than 30 kWp (+46% in numbers and +38% in terms of installed capacity). BIPV represented around 32 MW (corresponding to 13% of the total installed capacity), thanks to a special premium offered by the Swiss FiT and direct subsidy scheme (approx. 15% premium). Out of these 32 MW, 15 MW are in the residential segment. Ground-mounted applications represented less than 1 MW in 2017.

About 13 000 systems have been installed in 2017, corresponding to an increase of 40% compared to 2016. The largest segment are residential installations between 4-20 kW with more than 8 800 systems installed. This increase in number of systems came with a shift from larger to smaller installations and resulted in a decrease of the average size of a PV installation in Switzerland from 30 kW to about 20 kW.

Funding for Feed-in tariffs and direct subsidies continue to be limited and only projects announced before June 2012 have realistic chances to benefit from the Feed-in tariff scheme. As a result, the main drivers for market development in 2017 were self-consumption and direct subsidies for installations smaller than 30 kW, explaining the decrease in average system size.

In May 2017, the Swiss population accepted the new energy act (as part of the Energy Strategy 2050) with the objectives to:

- increase energy efficiency in buildings, mobility, industry and appliances
- increase the use of renewable energy by improving the legal framework and by promotion
- put a ban on new generation licences for nuclear power plants

The declared target for domestic production of renewable energy (excluding hydropower) is 11 400 GWh by 2035, corresponding to approximately 20% of the domestic electricity consumption. Thanks to an increase of the network surcharge from 1,5 CHFct/kWh to 2,3 CHFct/kWh from 2018 onwards (which applies, with some exceptions, to all electricity consumers), new funding for the promotion of renewable energies will be available. This will come however with a 20% reduction in feed-in tariffs as well as with a limitation of the promotion until 2023 (end of new commitments in the feed-in premium scheme) and 2031 (end of new one-time remuneration/direct subsidies).

From 2018 onwards, one-time remuneration will not be limited to installations smaller 30 kW, but can be obtained for system sizes up to 50 MW. Together with new regulations that facilitate and extend the possibility for collective self-consumption, these measures are expected to improve the conditions for the realization of larger PV installations in the coming years.

Operators of PV installations that are not benefiting from the (limited) FiT scheme can sell the electricity that is not consumed on site to their local District System Operator. Their buy-back tariffs vary considerably from one DSO to another and lie in the range of 0,04 to 0,2 CHF/kWh.

OTHER COUNTRIES

Bulgaria experienced a very fast PV market boom in 2012 that was fuelled by relatively high FiTs. Officially, 1,04 GW of PV systems were installed in this country with seven 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 2017.

In Croatia, PV systems with a capacity up to 5 MW are eligible for a FiT. According to the Croatian Energy Market Operator (HROTE), 52,43 MW of PV systems were installed at the end of July 2018. Three projects with an additional 1 MW already have signed contracts but are not yet installed

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 2,18 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. Then, to reduce the confidence of investors into PV in Czech Republic. in 2016, about 5 MW were installed in the country and 20 MW in 2017.

In 2009, Greece introduced a FiT scheme which started slowly until the market accelerated from 2011 until 2013, when 425 MW, 930 MW and more than 1 GW of new PV system capacity was installed respectively. This boom ended on 10 May 2013, when the Greek Ministry of Environment, Energy and Climate Change (YPEKA) announced retroactive changes in the FiT for systems larger than 100 kWp and new tariffs for all systems from 1 June 2013. During the first five months of 2013 almost 900 MW were installed and increased the total cumulative capacity to over 2,5 GW. About 2,4 GW were installed in mainland Greece and the rest on the islands. Since then, only a few tens of MW have been installed. The Greek Operator of the Electricity Market (ADMIE) reported about 2 094 MW of installed grid-connected PV systems over 10 kW and 351 MW of rooftop PV systems up to 10 kW at the end of 2017. Such numbers don't include non-connected islands. Almost nothing was installed in 2017. After the European Commission approved the new auction scheme on 4 January 2018, the first renewables auction in Greece was held on 2 July 2018. The auction was held by the Regulatory Authority for Energy (RAE) and had three categories:

- PV plants of 0,5 to 1 MW (83 projects with 53,48 MW of capacity were awarded with a weighted price of EUR 78,42 per MWh)
- PV plants between 1 and 20 MW (8 projects with 52,92 MW of capacity were awarded with a weighted price of EUR 63,81 per MWh)

- wind power plants between 3 and 50 MW (170,92 MW of capacity were awarded with a weighted price of EUR 69,53 per MWh).

The lowest bid was achieved in the second category with EUR 62,97 per MWh. A second auction is planned for the end of 2018.

In Hungary, the Hungarian National Renewable Action Plan (NREAP) required by the EU Renewable Energy Directive (2009/28/EC) foresees to reach a renewable energy share of 14,65% of its gross energy consumption by 2020. As a consequence of not meeting the trajectory set out in the NREAP, a new supporting scheme for electricity generation from RES was adopted in June 2016. The existing mandatory take-off system, guaranteeing a fixed price per kWh generated, was passed out on 31 December 2016. However, all project owners, which had submitted their application before this deadline, were still eligible for this scheme. In July 2017 the European Commission approved the new renewable support scheme. For systems with a capacity below 500 kW a feed in tariff (FiT) and for systems between 500 kW and 1 MW a feed-in premium (FiP) will be set at the beginning of each year. The approved internal rate of return (IRR) used to calculate the level of the FiT and FiP and the duration of support is 6,94%. Systems above 1 MW are eligible for a competitive FiP determined by a bidding procedure. In the first half of 2018, METAR, which finally came into force last October, already had some turbulences, when the government unexpectedly brought forward the application deadline for projects of 50 - 500 kW to April 26, whereas in the original government decree no deadline was foreseen. No date for a bidding for larger systems has been set yet. In 2017, Hungary connected about 90 MW of PV systems, increasing cumulative installed capacity to 380 MW by the end of 2017.

In Poland, the Polish National Renewable Action Plan required by the EU Renewable Energy Directive (2009/28/EC) foresees to reach a renewable energy share of 15,5% in the gross final energy consumption. Renewable electricity should reach 19,13% of the final energy supply by 2020. The Renewable Energy Act of 2015 went into force in July 2016 and replaces the previous green certificate system with an auction scheme. The first auction took place on 30th of December 2016 and the second on 29/30 June 2017. In 2016, Poland connected about 100 MW of PV systems, increasing cumulative installed capacity to 199 GW. About half of the capacity was installed under the old green certificate system, the other half are residential small systems.

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 two out of six 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 three. The total installed capacity reached 1,385 GW with only 3 MW installed in 2017. 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.

In Slovakia, following two years of rapid growth (2010/2011), the market fell by almost 90% with only 35 MW and 45 MW of new installations in 2012 and 2013 and has been always been below 5 W since. The total capacity of 545 MW is more than three and a half times the original 160 MW capacity target for 2020, published in the NREAP in 2010.

In the Russian Federation, the "Energy Strategy of Russia for the period up to 2035" is still in a draft stage and aims to reduce energy intensity by 6% by 2020 and 37% over the 2021–2035 period compared to 2014. Russia started to install solar PV capacity in 2010, and since 2013, capacity installations have accelerated with the installation of the first 1 MW plant in Kaspiysk, Dagestan. In May 2016, the Russian government set a target of 5,5 GW for the installation of renewable electricity capacities including wind, solar, small hydro up to 2024. Solar photovoltaic capacity should reach 1,75 GW. In 2017, about 60 MW of new PV capacity was installed in Russia, increasing the total capacity to around 600 MW (including approximately 400 MW in Crimea). As a result of the renewable energy auction in June 2017, Russia's Administrator of the Trading System allocated approximately 520 MW of PV capacity to be connected from 2018 onwards. In June 2018 about 150 MW of PV power was awarded to Hevel Solar and Fortum in an auction. Hevel Solar won three projects with close to 40 MW to be connected to the grid at the end of 2019, while Fortum won seven projects with 110 MW to be operational by 2021 and 2022.

The United Kingdom's PV market declined in 2017 to less than 1 GW, increasing the cumulative PV capacity to 12,7 GW. In 2016, PV systems with a power capacity of about 2,15 GW were connected to the grid. The old FiT scheme for systems up to 5 MW closed on 14 January 2016 and a new scheme opened on 8 February 2016, with different tariff rates and rules — including a limit on the number of installations supported in various capacity bands [GUK 2016]. The new scheme offers a 'Generation Tariff' for each generated kWh and in addition an 'Export Tariff' for up to 50% of the generated electricity, which is not consumed on-site at the time of generation (self-consumption). Both tariffs are adjusted each quarter and depend in addition whether or not the respective band caps are reached. Larger systems can participate in Contracts for Difference Allocation Rounds. In the first round, which was held in 2015 five projects with a total capacity of 72 MW won contracts with a strike price of 50 GBP (two projects with 33 MW) and 79,23 per MWh (three projects with 39 MW). However, two of the five projects were withdrawn, and one contract was cancelled. There is only confirmation of one project that was connected to the grid on 30 June 2016. The second round planned for October 2015 was cancelled and finally took place in April 2017, but solar was not included. The Renewable Obligation Certificate (ROC) scheme introduced in 2012 ended on 31 March 2017. But in general, this led to a substantial market decline, with even less installations foreseen in the coming years.

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In 2009, Ukraine introduced the "Green Tariff" policy, a feed-in tariff scheme for electricity generated from renewable energy sources [Bvr 2009]. In 2012, the Ukrainian Parliament ratified a bill to simplify households' access to the feed-in scheme and which came into force on 1 April 2013. The bill included a reduction in FiTs of 16% to 27%, depending on the type of installations. A second amendment of the Green Tariff System, which scrapped the local requirement scheme in force since 2013, was passed in June 2015. Instead, a local content premium was introduced. Plants using components produced locally are entitled to receive an additional premium on top of the regular feed-in tariff. With this amendment, the feed-in tariff levels in local currency are adjusted every quarter based on the exchange rate of EUR to UAH. A third amendment was adopted by the Ukrainian Parliament in December 2016 and went into force at the beginning of 2017. The amendment created different rates for renewable electricity produced by households and business entities. Installations benefiting from residential tariff cannot exceed 30 kW in size. In 2016, the Ukrainian government announced plans to open Chernobyl's nuclear wasteland for solar energy projects with a capacity of about 2,5 GW. About 220 MW of new PV power capacity was installed in 2017, thus increasing the total capacity to about 750 MW (excluding the approx. 400 MW in Crimea). The market expectations for 2018 are between 360 and 450 MW.

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 2017	68	TWh
HABITANTS 2017	9	MILLION
AVERAGE YIELD	2 175	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	103	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	978	MW_{DC}
PV PENETRATION	3	%

Israel installed 103 MW of new PV systems in 2017, whereas between 2012-2016 the country installed on average about 165 MW annually. In total, close to 1 GW of PV systems were operational in Israel at the end of 2017. Of this capacity, around 250 MW comes from PV projects exceeding 5 MW, while the remaining power is represented by residential and small commercial installations up to 50 kW (284 MW), and distributed generation PV plants up to 5 MW (downsized to 5 MW) (296 MW). On top of this, there are more than 146 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 for renewable energy. This could partially explain the decline of the PV market.

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.

MOROCCO

FINAL ELECTRICITY CONSUMPTION 2017	28	TWh
HABITANTS 2017	34	MILLION
AVERAGE YIELD	1 722	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	4,7	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	14,6	MW_{DC}
PV PENETRATION	0	%

Morocco has installed so far 4,7 MW of PV, which has brought the total installed capacity in the country to 14,6 MW.

The Moroccan market has been fully dominated by large-scale solar plants developed through public tenders. However, so far CSP as been favored and solar PV's market penetration remains marginal. Several utility-scale plants were being built at the end of 2017 and will go online during the year 2018. The Noor PV I amounts to approximately 177 MW split into three different sites. Noor PV II, aiming at the installation of 800 MW in total split into nine provinces should see the start of auctions starting in 2018. In 2019 another tender is expected, which might incorporate high levels of local content to incentivize local manufacturing, but this has not been officially announced. It shows a real interest from the Moroccan government to deploy massively PV in the country and start a real competitive manufacturing industry.

Distributed PV was not supported by a dedicated scheme in 2017.

The need for clean electricity is reinforced by the growing electricity demand which is already higher than total domestic generation capacity, and keeps increasing at a regular pace, boosted by economic growth (4 to 5% a year). Driven by the increase of electricity access and of living standards, combined with demographic pressure, electricity demand in the country rose by 6,6 per year on average during the last ten years. As the electrification rate is extremely high, attention can be focussed on the development on centralized electricity generation source. Off-grid in that respect will continue to be rather limited.

The European Bank for Reconstruction and Development (EBRD) has issued a tender to select consultants that will have to provide assistance to Morocco's government for the assessment of the country's power system to absorb more power injected by renewable energy power plants. The World Bank announced in June 2018, 125 MUSD in additional support for Morocco's adoption of innovative solar technology, as part of the national goal of developing the country's world-class solar and wind energy resources to reduce the dependence on fossil fuels and move toward a green energy future.

The currently developed solar PV plants are a critical component of the country's goal of producing 52% of its electricity through renewable energy by 2030 (43% by 2020). Morocco aims to increase its current installed electricity production capacity, which is around 8 GW, to 14,5 GW by 2020. Of this, 2 GW is expected to come from solar PV by 2020. The cumulative capacity of solar PV is aimed to equal 3 GW by 2030.

TURKEY

FINAL ELECTRICITY CONSUMPTION 2017	75	TWh
HABITANTS 2017	81	MILLION
AVERAGE YIELD	1 527	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	2 588	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	3 427	MW_{DC}
PV PENETRATION	1	%

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 increased by 2 588 MW in 2017.

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 three licensed PV plants have been installed in Turkey with a total installed capacity of 17,9 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 "unlicensed" projects. 613 small-scale, unlicensed, PV power plants (up to 1 MW) are already in operation with an installed capacity of 3402,8 MW in 2017. Cumulative grid-connected installed PV power in Turkey reached to 3 420,7 MW by the end of 2017. Huge increase in

MIDDLE EAST AND AFRICA / CONTINUED

distribution costs of PV power plants forced the investors to install PV power plants before the start of 2018. The distribution costs amounted to 0,7597 TRYkr/kWh in 2016, 2,5628 TRYkr/kWh in 2017 and will be 11,31 TRYkr/kWh in 2018. For example, for a PV power plant with an installed capacity of 1 MW, assumed to generate around 1 600 MWh of energy, the expenditure will be 22,9% of the total endorsement gained from the energy sales for the annual distribution cost. Therefore, the investors were in a rush in the last month for getting operation approval for their PV power plants before December 31, 2017.

The remuneration of PV projects as 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.

The Regulation on YEKAs (Renewable Energy Designated Areas) has come into force following its official promulgation dated October 9, 2016. YEKAs in privately owned or state-owned lands identify the feasible areas for large-scale renewable energy projects. While projects conducted within the framework of YEKA benefit from investment incentives, companies with the highest rate of domestic transfer of technology and production will be given priority. The first bidding was held in Karapinar, Konya with an allocated capacity of 1 GW. The project is a major step for large-scale renewable energy investments. The project is developed by one investor with the requirement to set up a manufacturing facility and conduct research and development activities. The bidding was conducted in March 20, 2017. The tender was conducted in a reverse auction and the ceiling price per megawatt was set at 8 USDcent/kWh. For the tender for the Karapinar Renewable Energy Resource Area (YEKA), a consortium has been awarded by submitting the lowest bid, 6,99 USDcent/kWh, to construct the largest PV power plant with an installed capacity of 1 GWac in Turkey. The purchase guarantee price is valid for 15 years. As part of the award criteria, the consortium will build a fully integrated solar cell and module factory with a capacity of 500 MW within the next 21 months. The new facility consists of integrated ingot, wafer, cell and module processes. In addition to the manufacturing facility, the consortium will establish on-site research and development (R&D) center with 100 permanent employees.

By the end of 2017, the Turkish Energy Market Regulatory Authority (EPDK) published a draft net metering regulation for rooftop PV installations with a power range of 3 kW to 10 kW. Households in Turkey will be able to produce solar energy by installing rooftop and façade solar panels and therefore supply their own electricity.

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.

SOUTH AFRICA

FINAL ELECTRICITY CONSUMPTION 2017	220	TWh
HABITANTS 2017	55	MILLION
AVERAGE YIELD	1 733	kWh/kW
2017 PV ANNUAL INSTALLED CAPACITY	13	MW_{DC}
2017 PV CUMULATIVE INSTALLED CAPACITY	1 482	MW_{DC}
PV PENETRATION	5	%

South Africa became the first African PV market in 2014 with around 900 MW installed, mostly ground mounted, but the momentum didn't last in 2015. In 2016 some 509 MW were installed and then nothing in 2017. At the end of 2017, the total installed capacity for utility-scale PV plants reached 1,48 GW, the largest installation level in Africa. The large majority of this capacity has been in large scale ground mounted systems, while the rooftop solar photovoltaic market, despite its enormous potential, remains dormant. Small distributed generators have possibly the potential to grow rapidly (around 500 to 1 000 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. In addition, more than 100 000 small-scale systems have been installed, possibly more than 200 MW, but actual numbers are not available yet.

The Renewable Energy Independent Power Producer Procurement Programme

A variety of mid- and long-term interventions have 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 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 compared to the largest markets but almost all countries saw a small development of PV in the last years and some 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 0,023 USD/kWh. At the beginning of 2018, more than 1 GW was operational in these countries, with 353 MW in Algeria, 30 MW in Egypt, 467 MW in Jordan, 10 MW in Kuwait and 323 MW in the UAE.

But many more plants were being built, such as 1,8 GW in Egypt, close to 2 GW in the UAE (Dubai, Abu Dhabi) and 453 MW in Jordan. Dubai alone will install 1 000 MW in the coming years and more has been announced. Jordan at one time announced 200 MW, then it aimed for at least 1 GW of PV in 2030, but they will be installed rapidly. Qatar launched its first tender for 200 MW in October 2013. Saudi Arabia launched a tender in 2017 which could have provide most probably the lowest bid ever seen in PV. However, the most astonishing event in the region was the announcement of a 200 GW plan by 2030 in the Saudi kingdom. Why such a large plan raises questions, and given some uncertainties on the realization, it far exceeds the electricity demand of the country, which would imply a complete rethinking of the energy system of the country.

Other countries in the Middle East have set up plans for PV development in the short or long term. Bahrain has announced the development of 200 MW, Kuwait aims for 1 GW, Oman has launched tenders for at least 600 MW (out of a plan to reach 4 GW of RES capacity by 2030), Tunisia for 80 MW, Libya 50 MW and Lebanon for 50 MW.

In Africa, besides South Africa, the fastest mover was Egypt, which has announced plans to develop PV, at GW-scale.

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 Democratic Republic of Congo, 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.

Large-scale PV plants have been announced in Burkina Faso, Mozambique, Namibia, Cameroon, and Kenya (where PPA were signed at a quite high price before the announcement of moving towards tenders) to name a few. Nigeria remains a market with a high potential but little progresses have been seen so far. The question of African power markets is essential since many countries have a small centralized power demand, sometimes below 500 MW. In that respect, the question is not only to connect PV to the grid but also to envisage building infrastructure and developing electricity demand through interconnected grids.

TABLE 2: 2017 PV MARKET STATISTICS IN DETAIL

COUNTRY	2017 ANNUAL CAPACITY (MW)			2017 CUMULATIVE CAPACITY (MW)		
	GRID-CONNECTED		TOTAL	GRID-CONNECTED		TOTAL
	DECENTRALIZED	CENTRALIZED		DECENTRALIZED	CENTRALIZED	
AUSTRALIA	1 186	124	1 309	6 789	473	7 261
AUSTRIA	172	0	172	1 262	2	1 264
BELGIUM	289	0	289	3 877	0	3 877
CANADA	114	135	249	907	2 006	2 913
CHILE	9	883	892	14	2 023	2 037
CHINA	19 440	33 620	53 060	29 730	101 042	130 772
DENMARK	24	36	60	690	217	907
FINLAND	43	0	43	69	1	70
FRANCE	413	462	875	4 986	3 060	8 046
GERMANY	1 299	477	1 776	31 677	10 815	42 492
ISRAEL	68	35	103	430	548	978
ITALY	297	117	414	8 106	11 577	19 682
JAPAN	3 962	3 488	7 450	33 205	16 123	49 329
KOREA	90	1 281	1 371	641	5 231	5 873
MALAYSIA	49	0	49	391	0	391
MEXICO	95	190	285	272	377	649
NETHERLANDS	853	0	853	2 895	43	2 938
NORWAY	17	0	17	31	0	31
PORTUGAL	32	12	44	234	319	553
SOUTH AFRICA	69	0	69	285	1 474	1 759
SPAIN	144	4	148	92	5 192	5 284
SWEDEN	113	3	115	294	14	307
SWITZERLAND	241	1	242	1 898	4	1 902
THAILAND	0	251	251	0	2 667	2 667
TURKEY	0	2 588	2 588	2	3 425	3 427
USA	4 451	6 231	10 682	20 596	31 042	51 638
TOTAL IEA PVPS COUNTRIES	**33 470**	**49 938**	**83 407**	**149 371**	**197 674**	**347 045**
NON IEA PVPS COUNTRIES			**13 401**			**48 470**
REST OF THE WORLD ESTIMATES			**1 633**			**4 906**
GRID CONNECTED			**98 441**			**400 421**
ESTIMATED OFF GRID			**506**			**2 873**
TOTAL GRID + OFF GRID			**98 947**			**403 294**

SOURCE IEA PVPS 8 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 2017, the price of PV systems, as IEA PVPS has observed, 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.

However, 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 in 2017, 99% of the volume of the market is still dependent of support schemes or adequate regulatory frameworks and the comparison with the historical data shows a global stability. Of course, as it is in volume, China is heavily impacting theses conclusions. In Figure 14, we can see that, until the end of 2017, less than 1% of the PV installations were driven by pure self-consumption (mainly in Spain, Portugal and Chile).

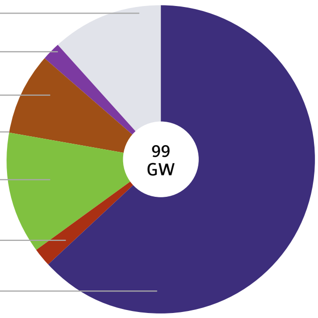
Globally, about 75% of the PV installations are receiving a predefined tariff for part or all of their production. It reaches 83% in centralised grid connected pv systems and only 61% in the distributed PV market.

Subsidies aiming at reducing the upfront investment (or tax breaks), used as the main driver for PV development were less used in 2017 than before and represented around 13% of the volume.

Incentivised self-consumption, including net-billing and net-metering, was the main incentive in 2017 for 8,5% 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 2%.

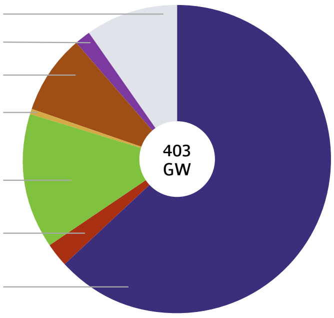
PV MARKET DRIVERS / CONTINUED

FIGURE 13: 2017 MARKET INCENTIVES AND ENABLERS



SOURCE IEA PVPS & OTHERS.

FIGURE 14: HISTORICAL MARKET INCENTIVES AND ENABLERS



SOURCE IEA PVPS & OTHERS.

The calls for tenders increased in volume in 2017 thanks to new countries using this legal tool to attribute remunerations to PV projects under certain conditions. Jordan, Egypt, 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 12% of the world market in 2017 and can take various forms integrating 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 2017 and 2018 important volumes, such as in India, Spain, Mexico, Chile and many 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.

THE SUPPORT SCHEMES

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 as shown in Figure 13. While FiTs still represent more than 66% of the 2017 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), as well as 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 2017, 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. Some countries, such as Malaysia, have decided in 2017 to stop FiT for new solar projects and go for other support mechanisms like net-metering (NEM) and self consumption scheme.

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. Most continents 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 12% of all PV installations in 2017 (and this should increase again 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 it for utility-scale plants. In Latin America, Peru, Mexico and Brazil, just to mention the most visible, have implemented such tenders. In India, Chile, Mexico, the UAE and most recently Saudi Arabia, the bids are reaching extremely low levels, now significantly below 30 USD/MWh in several cases and most probably below 20 USD/MWh in the sunniest places. Table 3 shows some of the most competitive tenders in the world.

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 (Japan, Germany, France, South Africa, etc.) or technology neutral (the Netherlands, Poland, UK,Denmark). 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.

TABLE 3: THE MOST COMPETITIVE TENDERS IN THE WORLD UNTIL Q1 2018

REGION	COUNTRY/STATE	USD/MWh
LATIN AMERICA	MEXICO	20,57
LATIN AMERICA	CHILE	21,48
LATIN AMERICA	BRAZIL	35,58
EAST ASIA	INDIA	41
LATIN AMERICA	ARGENTINA	40,4
INDIA	INDIA	46
MIDDLE EAST	ARMENIA	46
WESTERN EUROPE	GERMANY	48,76

EURO exchange rate calculated on the 01.04.2018
1 EURO = 1.2314 USD

SOURCE IEA, Becquerel Institute

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.

Additional Constraints

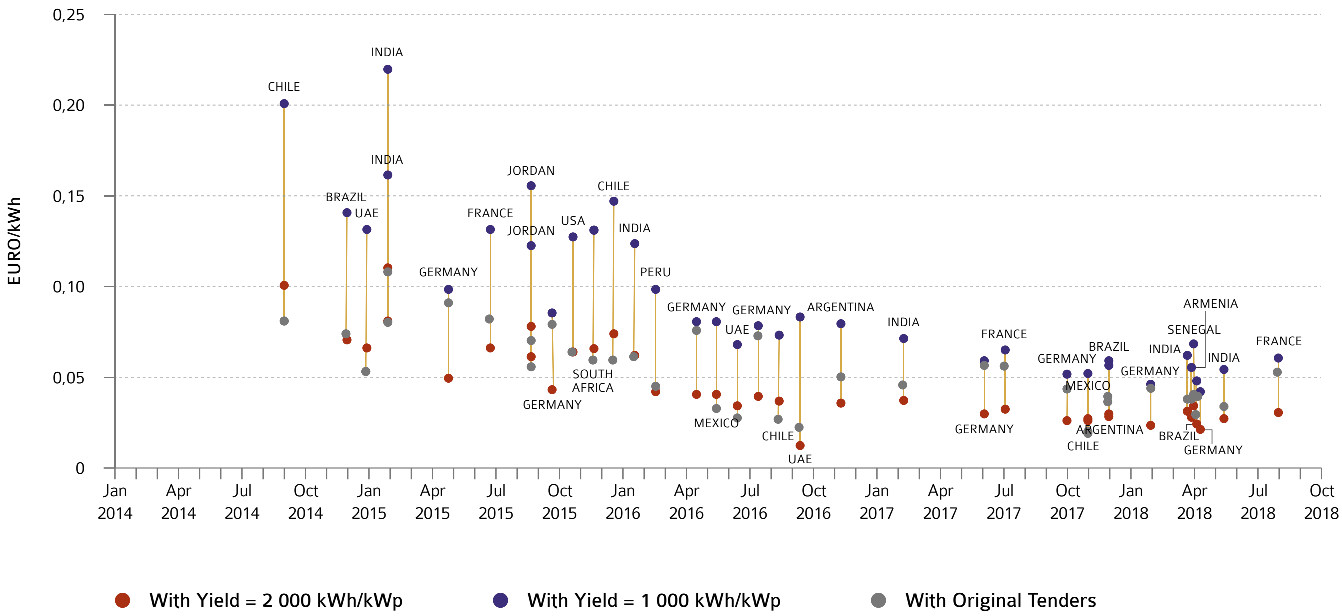
The ease of implementing FiT allows its use when PV is approaching competitiveness: Germany added a 90% cap in 2012 to the amount of electricity that could benefit from the FiT system, pushing for either selling the excess on the electricity market (at a quite low price, between 30 to 50 EUR/MWh in 2017), 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 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.

THE SUPPORT SCHEMES / CONTINUED

FIGURE 15: NORMALIZED LCOE FOR SOLAR PV BASED ON RECENT PPA PRICES 2014 - Q2 2018



SOURCE IEA PVPS, BECQUEREL INSTITUTE.

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.

COMPETITIVE POWER PURCHASE AGREEMENTS

While FiT are paid in general by official bodies or utilities, looking for Power Purchase Agreements (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.

DIRECT SUBSIDIES AND TAX CREDITS

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 to mention a few. 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 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.

SELF-CONSUMPTION AND NET-METERING

With around 37% of distributed PV installations in 2017, it seems logical that a part of the PV future will come from its deployment on buildings, in order to provide electricity locally. 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 time frame 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);
- 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 Sweden, some utilities allow net-metering while in the 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 2017 (Israel, Jordan, UAE (Dubai) and Chile). Portugal is setting up a net-billing scheme.

The main question that developed in 2017 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 self-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 are tested in some countries (Austria, Netherlands, France, Mexico, Switzerland, etc.). Some utilities even proposed it before the regulations were officially published (as in Austria or Switzerland). In this case, we already see innovative products mixing PV installations, PV investment and virtual storage. This evolution will be scrutinized in the coming years since it.

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. One must be careful when looking at self-consumption schemes since the same vocabulary can imply different regulations depending on the case. The best example is in the USA, with the wording "net-metering" being used for different self-consumption schemes in different states.

THE SUPPORT SCHEMES / CONTINUED

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 greenhouse 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 2018 a new directive defined 2030 objectives The relatively low level of ambition of these binding targets (32% 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.

COST OF SUPPORT SCHEMES

The cost of these 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 specific 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.

China: On May 31, 2018, the government imposed a limit to PV market development. That limit originated from the government willingness to control the market and avoid rising retail electricity prices. While this was only a part of the explanation, it shows that the impact of retail electricity prices can be a concern also in the largest world PV market.

Denmark: Support measures for PV (and other REs) have so far mainly been financed by the so called Public Service Obligation (PSO) administered by the state owned TSO. The money involved was collected as a small levy on every kWh sold. Following discussions with the European Commission on the compliance of the PSO scheme with EU state aid regulations it was in 2016 decided to phase out the PSO scheme over some years and in the future use the state budget to provide the financing of eventual RE support measures; however no PV related support measures are expected in the coming years.

France: The CSPE surcharge part for PV amounted to 2,8 BEUR in 2017, or around 22,5 EUR/MWh with partial or whole exonerations possible for certain sectors (energy intensive industries, transport, etc.). For residential consumers in France, support for photovoltaics represents approximately 5% the cost of kWh consumption in 2017.

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 2018, EEG surcharge is 6,8 EURcts/kWh. End users must pay the value added tax (19%) on this surcharge so that the costs imposed on private households increases to 8,1 EURcts/kWh for all renewable energies.The contribution of PV is considered as small compared to wind in the last year.

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.

Japan: The surcharge to promote renewable energy power generation for an household was set at 2,64 JPY/kWh in April 2018 and 2,90 JPY/kWh from May 2018 to April 2019. 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 133,1 TWh as of the end of September 2017, approaching 5,4 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.

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 is 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.

SOFT COSTS

Financial support schemes have not always succeeded in starting the deployment of PV in a country. Several examples of well-designed support 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 or Swiss 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, etc.) 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.

SUSTAINABLE BUILDING REQUIREMENTS

With more than 35% 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 Belgium, Flanders introduced a similar measure since 2014. The first results shows that PV is chosen in more than 85% of the new buildings. 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.

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 2017 few countries provided specific subsidies for storage system development.

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. In Spain, The Catalan Government opened a line of financial support for the purchase of batteries for solar photovoltaic self-consumption in domestic and communities installations. Also in Sweden subsidies were allocated for promoting energy storage owned by private households. Canada has established several innovation funds that have given rise to solar projects with electricity storage. The most relevant programmes in 2017 were Smart Grid Fund, promoted by the province of Ontario, and the Federal Government's Smart Grid programme. The latest is a program promoted at the federal level that is expected to result in support for combined solar and storage projects all over across the country. In the USA, several states including California has set up an energy storage mandate. In May 2018, New Jersey became the seventh state with an energy storage mandate, requiring 2 GW of storage by 2030. Other leading states include California, with a 1,8 GW target (1,3 GW by 2025) and New York (1,5 GW by 2025). At the end of 2017, 85 MW were operational.

In 2017, the National Development and Reform Commission of China published the "Guidance opinion on promotion of energy storage technological and industrial development". The document called for development of power storage to promote pilot renewable energy applications, support the grid, and allow the participation of power storage in the auxiliary service market. Other aspects associated to the participation to electricity markets were also mentioned. China is a key global manufacturer of Li-Ion batteries and its electric vehicles markets is the largest in the world.

In the overseas' departments of France (including Corsica), a second call for tenders for 50 MW of PV systems above 100 kW with storage has been initiated in 2016, aiming at increasing the grid stability. The winning candidates for this Call have been announced in August 2017. Out of 356 MW of submitted projects, 52 MW were selected with an average contract tariff of 204 EUR/MWh in 2016 while in 2017, 67 projects representing 63 MW were granted 200 EUR/MWh during peak hours. 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. The increasing interest has for distributed storage systems led the major distribution grid operator Enedis to publish a technical note on grid connection conditions for stationary storage systems in October 2017.

Japan is as well trying to increase the numbers of projects to install storage batteries but with still limited subsidies and high costs. In the past years storage batteries for residential applications were part of a subsidy program to accelerate the development of net zero energy houses. This subsidy program was distributed in ten different rounds of public invitation which received 7 747 applications in total (7 693 projects were selected). Installation of storage batteries was not subsidized within the budget for Fiscal year 2017.

CONCLUSION

Once again in 2017, the most successful PV deployment policies were based on FiT policies or direct incentives (including tax breaks). The growth of the PV market in China (mainly driven by FiT and direct incentives), the second place of the US market (tax breaks, net-metering), but also the high market level in Japan show how important these incentives remain. In parallel, the projects granted through tenders have grown significantly in 2017 but competitive PPA (or simply competitive PV installations) remain a small part of the PV market.

With declining costs of PV electricity generation, the question of alternative support schemes has gained more importance in several countries. The emergence of schemes promoting (normal, virtual or collective) 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.

Until last year, there was a concentrated growth of the PV market in the utility-scale segment. The significant change seen in 2017 is the growth of the distributed PV market. However, the major outcome of 2017 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.

In a nutshell, PV continues to depend on support policies to develop massively. While all energy sources are subsidized, this should not be considered as different for PV.

CONCLUSION / CONTINUED

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

COUNTRY	DIRECT CAPITAL SUBSIDIES	TAX INCENTIVES	FEED-IN TARIFF / FEED-IN PREMIUM	NET-METERING / NET-BILLING	SELF- CONSUMPTION	COLLECTIVE & VIRTUAL SELF- CONSUMPTION	RPS / GREEN CERTIFICATES	SUSTAINABLE BUILDING REQUIREMENTS	BIPV INCENTIVES	STORAGE INCENTIVES	EV INCENTIVES
AUSTRALIA	G		G	G	G		G	G		G	
AUSTRIA			G		G			G	G	G	G
BELGIUM		G		G	G		G	G			G
CANADA	G	G	G	G	G	S		G			G
CHINA			G	G	G		S		G	S	
DENMARK					G			C			
FINLAND	G	G		G	G			G			
FRANCE			G	G	G	S		G	G		G
ITALY	G	G		G	G	S		G		G	
JAPAN	G	G	G		G		G	G			
MALAYSIA	S	G	G	G	G			G	G		
PORTUGAL			G		G		G	G			G
SPAIN					G	G		G	G	G	G
SWEDEN	G	G	G	G	G	G	G	G		G	
SWITZERLAND	G	G	G	G	G	S	G	G	G	G	G
USA	G	G	G	G	G	G	G				G

S This support scheme started in 2017

G This support scheme has been used in 2017

C This support scheme has been cancelled in 2017

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 2017, including project development as well as operation and maintenance (O&M) is also briefly presented. This chapter is intended to provide a summarized overview of the PV industry: more detailed information on the PV industry of each IEA PVPS member country can be found in the relevant National Survey Reports.

As presented above in this report, the global PV installed capacity reached 99 GW in 2017, achieving a 29% year-on-year growth. The production of polysilicon, ingots, wafers, PV cells and modules also increased to record levels. Similar to the 2016 trend, the Chinese market influenced the growth of the entire global PV production significantly. In 2017, China installed 53 GW, about 24 GW in the first half of the year, and about 28 GW in the second half of the year. Major companies supplying PV modules to the domestic market increased shipment volume, and as a result, the global PV cell/module production grew greatly, driven by China.

In addition to the market growth, expansion of production capacity was also reported. Plans to expand production capacity were announced in China as well, however, trade conflicts with some areas influenced the strategies of PV manufacturing sites, as in the previous year. Plans to expand production capacity were announced in Vietnam and Turkey, as well.

Throughout 2017, the price of a PV module (spot price of multi-crystalline silicon (mc-Si) PV module) gradually decreased from 35 cents/W in the start of the year to 31 cents/W by the end of the year. This resulted in reduction of the initial installation cost of PV systems.

THE UPSTREAM PV SECTOR

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

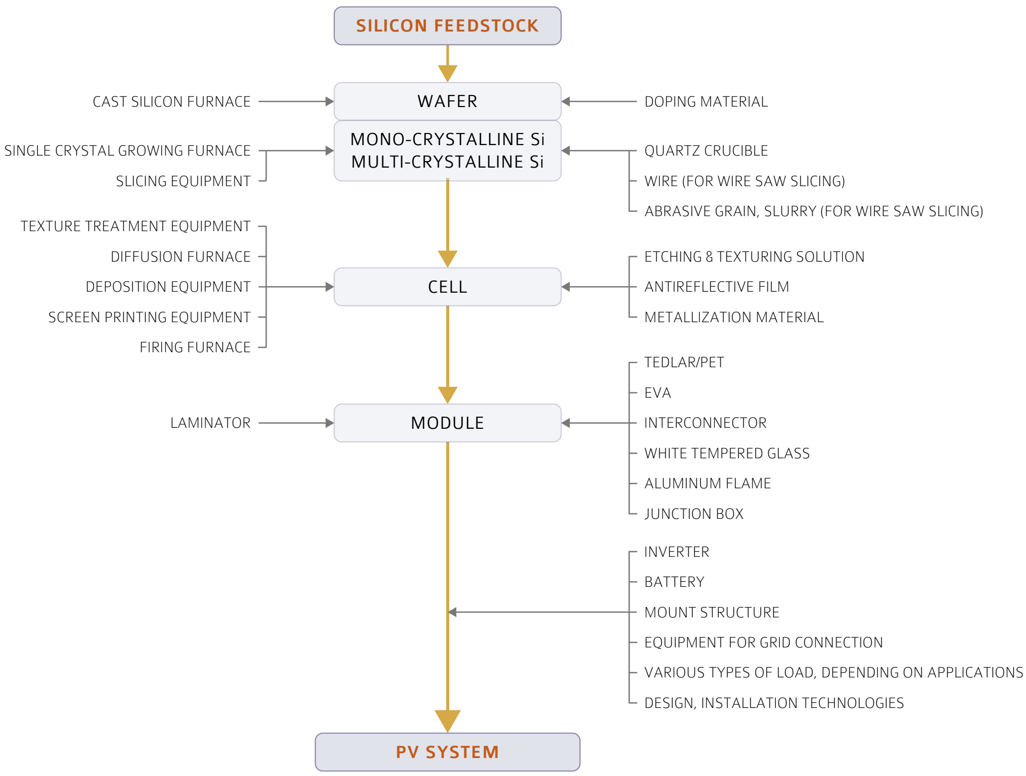
POLYSILICON PRODUCTION

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.

It is estimated that polysilicon production increased from 400 000 tons in 2016 to approx. 432 000 tons in 2017. Polysilicon production for semiconductors increased slightly to reach around 32 000 tons in 2017. The production volume of polysilicon for solar cells accounted for about 93% of total production of polysilicon in 2017.

THE UPSTREAM PV SECTOR / CONTINUED

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



SOURCE IEA PVPS & OTHERS.

Global polysilicon production capacity continuously increased. As of the end of 2017, it reached around 540 000 ton/year, from about 470 000 ton/year in 2016. Tier 1 manufacturers accounted for 55% of the global production capacities in 2017, with about 300 000 t/year, the same as in 2016.

In 2017, it is estimated that an average 4,9 g/W (minimum around 4 g/W) of polysilicon was used for solar cells. The amount of polysilicon used per W, known as consumption per unit, decreased yearly due to improvement of conversion efficiency and thinning of wafers. The consumption per unit decreased by 35% from 8 g/W of 2008.

The polysilicon spot price fluctuates, reflecting on the situation of the market. At the end of January 2017, its price was between 16,2 - 16,6 USD/kg, supported by the steady production of solar cells and stable demand for silicon material in the beginning of the year. The price dropped to around 13 USD/kg in March affected by overstock in China. Later, the price gradually recovered due to increase in demand and increased by about 20 to 30% in the second half of the year, and reported higher in the 17 USD range by the end of December 2017. However, the fluctuation of polysilicon spot price is limited since pressure for price decrease in the downstream sector is strengthening, and many companies procure polysilicon under long-term supply agreements. Regarding the long-term supply agreements signed when polysilicon supply was tight (2006 to 2010), legal disputes between PV cell/module manufacturers and polysilicon manufacturers continue 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 2017 was between 40 kWh/kg and 50 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 produces 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. In 2017, GCL Poly Energy (China) acquired FBR technology from SunEdison (USA) for manufacturing polysilicon. Shaanxi Non-Ferrous Tian Hong REC Silicon, a joint venture established by REC Silicon (Norway) and

Shaanxi Non-Ferrous Tian Hong New Energy (SNF) (China), constructed a FBR-based polysilicon manufacturing factory (18 000 t/year) in 2017, and reported to have started test production in the first half of 2018. It is planning to shift to full-scale production in the second half of 2018.

Another lower cost process is the metallurgical process that enables to produce polysilicon directly from metallurgical silicon. Silicor Materials (USA) announced construction of a 19 000 ton/year polysilicon factory with the 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 2017. China continued to be the largest producer and consumer of polysilicon in the world with 22 polysilicon manufacturers and a production of 242 000 tons of polysilicon in 2017, up by 24,7% from 2016, accounting for about 56% of the total global production. The production capacity of polysilicon in China increased by 66 000 ton/year (increase of 31%) compared to the previous year and reached 276 000 ton/year. The consumption of polysilicon for solar cells in China was 330 000 tons, and China imported 150 000 tons of polysilicon in 2017, up by 6,4% from 2016. Most of the imports were from Germany, South Korea as well as Malaysia.

The largest polysilicon manufacturer in China was GCL-Poly Energy (Jiangsu Zhongneng Polysilicon Technology Development), which possesses 74 000 ton/year capacity and produced 74 818 tons in 2017. GCL-Poly Energy was also the world's largest polysilicon manufacturer. The company announced a plan to move its 20 000 ton/year plant in Jiangsu Province to Xinjiang Wiggle to reduce electricity cost and expand production capacity by 40 000 ton/year there. China's second largest polysilicon manufacturer was Xinte Energy (TBEA) that produced 29 400 tons, followed by Daqo New Energy that produced 20 200 tons. New investment in facilities by each company not only contributed to the expansion of production capacity but also helps renew obsolete facilities aiming for improvement of quality and cost reduction towards making higher efficiency solar cells and supplying semiconductor-grade polysilicon.

Germany has the domestic polysilicon production capacity of over 60 000 ton/year. Wacker Chemie possesses domestic production capacity of 60 000 ton/year, and possesses 80 000 ton/year added with the production capacity in the USA. Wacker Chemie's polysilicon manufacturing factory in Tennessee, USA, stopped production in September 2017 due to fire, but resumed operation in the second quarter of 2018. In order to avoid anti-dumping duties in China which are over 50%, the US factory manufactures polysilicon for solar cells targeting countries other than China or for semiconductor-grade polysilicon for China. The company produced about 70 000 tons of polysilicon in 2017, and ranked second in the global polysilicon manufacturing.

South Korea reported 82 000 ton/year of polysilicon production capacity in 2017. The country's largest polysilicon manufacturer OCI acquired the Malaysian polysilicon factory (13 800 ton/year) from Tokuyama (Japan) in May 2017 and its total effective production capacity home (52 000 ton/year) and abroad reached 69 000 ton/year. It produced 49 000 ton of polysilicon in Korea, 11 000 ton of in Malaysia, totaling 60 000 ton in 2017, and ranked third globally. The company announced to focus on high purity polysilicon corresponding to increase in demand of p- type sc-Si wafers. Other Korean manufacturers are Hanwha Chemical, Hankook Silicon and SMP (joint venture of LOTTE Fine Chemical and GCL-Poly Energy).

The USA increased their polysilicon manufacturing capacity to 90 000 ton/year including Wacker Chemie's Tennessee Factory, as mentioned above. However, the polysilicon production in the USA is in a decreasing trend due to anti-dumping duties imposed by China and the bankruptcy of SunEdison.

Canada, USA and Norway reported activities of polysilicon manufacturers adopting metallurgical process aiming at lowering the production cost. Silicor Materials (USA) owns a factory in Canada and is building a manufacturing factory in Iceland. Elkem Solar in Norway is estimated to have produced 6 500 tons of polysilicon in 2017.

The production capacity of polysilicon is in an expanding trend, against the backdrop of the increase of demand of polysilicon for solar cells, and it is expected to reach 695 000 ton/year in 2018, an increase of 30% compared to 2017. However, the situation of the market worsened due to China's policy to lower their national targets announced on May 31, 2018. As a result, it was reported that 12 manufacturers, which account to 27,7% of the total polysilicon production capacity in China, suspended operation of production lines arguing facility inspection, repair, etc., as of June 22, 2018. A major Korean manufacturer, OCI, was reported to have partly suspended production as well. However, it is expected that oversupply will not be resolved in the short-term. On the other hand, demand for high quality wafers for solar cells with high conversion efficiency is increasing, and it is possible that there will be a supply shortage of high purity polysilicon.

INGOT & WAFER

To produce mono-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: Mono-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 manufacturers are in many cases wafer manufacturers. In addition to major ingot/wafer manufacturers, some PV modules manufacturers such as JinkoSolar (China), JA Solar (China), Yingli Green Energy (China), REC Solar (Singapore), Canadian Solar (Canada/ China), Hanwha Q Cells (Korea) also partly manufacture silicon ingots and wafers for their in-house uses. This situation makes it difficult to track down the entire picture of ingot and wafer 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

THE UPSTREAM PV SECTOR / CONTINUED

advantages. In 2017, it is estimated that about 106 GW of c-Si wafers were produced. It was an increase of 40% compared to 2016 with 75 GW. The wafer production capacity, as of 2017, is estimated to be 125 GW/year, a 25% increase compared to 2016 with 100 GW/year. As for wafers, manufacturers announced to continue enhancing their production capacities. By the end of 2018, global production capacity may reach about 160 GW/year, which raises a concern of oversupply.

The spot price of c-Si wafers as of January 2017 was 0,63 to 0,68 USD/wafer for mc-Si wafers (156 mm x 156 mm), and 0,80 to 0,86 USD/wafer for sc-Si wafers, which increased slightly due to lack of supply. The spot price of mc-Si wafers decreased to 0,55 USD/wafer in April 2018, while that of sc-Si wafers stayed at the 0,8 USD/wafer level due to lack of supply for demand towards PERC PV module. For mc-Si wafers, the price recovered in the second half of the year due to increase in demand, and the price for high quality wafers reached the 0,66 USD/wafer (156 mm x 156 mm) level by the end of August, but fell to 0.62 USD/wafer by the end of 2017. For sc-Si wafers, expansion of production capacity progressed, and, as a result of oversupply, it was reported that the price went below the level of 0,70 USD/piece at the end of 2017.

China has a strong presence in wafer production, as well. The wafer production in China in 2017 was 87,6 GW, a 39% increase from the previous year, accounting for about 83% of the global production. The wafer production capacity in China increased from 82 GW/year in 2016 to 105 GW/year in 2017. GCL-Poly Energy was the largest wafer manufacturer both domestically and globally in 2017 following 2016, with production capacity of 22 GW/year and produced 23,9 GW of wafers. The second place was held by LONGi Green Energy Technology (China), that produced 10,8 GW with the production capacity of 15 GW/year. Jinko Solar ranked third and produced 6,8 GW of wafers with the production capacity of 8 GW/year.

As for other IEA PVPS member countries, production capacities in Korea and Japan remain small compared to China. Malaysia, Norway and the USA also reported ingot/wafer production activities. Besides IEA PVPS member countries, Taiwan is a major manufacturer of wafers for solar cells with about 10 companies including PV module manufacturers producing wafers, and the total production capacity is over 6,5 GW/year. In Singapore, REC Solar of Norway is producing wafers for solar cells for their in-house uses at its factory with the production capacity of about 1 GW/year.

Regarding wafers, improvement of quality is required for both sc-Si and mc-Si wafers. This is because the demand for high performance wafers is increasing since conversion efficiency requirements were raised under the Top Runner Program, a tender scheme in China which has performance requirements. As for mc-Si wafers, efforts are being made on the improvement of quality and yield through various improvements such as improvement of purity of crucible and coating of inner wall of crucibles.

To reduce the costs of wafer production, the utilization of diamond wire saw (DWS), which improves efficiency and reduces processing time through reduction of kerf loss, advanced in 2017. While DWS is mainly used for sc-Si wafers, the adoption of DWS for mc-Si wafers has been accelerated. "Black silicon" substrates applying new surface texture processing technology such as reactive ion etching (RIE) is progressing for texturing, which had been an issue for mc-Si wafers.

Startup companies in the USA and Europe are developing new processes to manufacture wafers without conventional ingot growing and wire-sawing processes. 1366 Technologies (USA) announced that it achieved 20,3% of conversion efficiency with PERC solar cell using its kerfless wafers directly processed from molten polysilicon. Leading Edge Crystal Technologies (USA) is conducting development of wafer production process with crystal ribbon. IMEC (Belgium) announced it achieved 22,5% of conversion efficiency with solar cells using Direct Gas to Wafer technology by Crystal Solar (USA). NexWafe (Germany) is planning to conduct financing and start operation of c-Si wafer production lines with production capacity of 5 MW/year.

SOLAR CELL AND MODULE PRODUCTION

Global solar cell (crystalline silicon solar cell and thin-film PV solar cell) production in 2017 is estimated to be around 104 GW, a 32% increase year on year. As in the previous year, China reported the world's largest production of solar cells. In China, 72 GW of solar cells were produced in 2017, a 16,8% increase over the previous year (51,2 GW in 2016). Solar cell production capacity in China is about 83 GW/year.

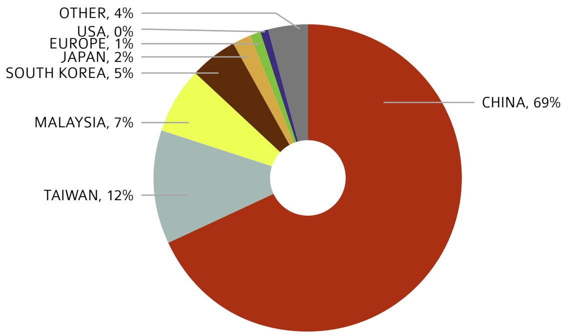
As shown in Figure 17, China's solar cell production volume accounts for 72% of the world total.

The export of solar cell increased steadily in 2017. Statistics from the customs office showed that China exported about 4,8 GW of solar cells to 128 countries and regions, with an export value of 990 MUSD, an increase of 22,8% on a year-on-year basis, accounting for 6,8% of total PV product export value.

IEA PVPS countries that reported production of solar cells are China, Malaysia, Thailand, South Korea, Japan, Germany, and USA. Major non IEA PVPS countries manufacturing solar cells are Taiwan, Philippines, Singapore, India, and Vietnam. Taiwan has more than 13 GW/year of production capacity, the second largest-scale in the world following China, both in terms of production capacity and production volume. Establishment of production bases in Vietnam is advancing to avoid impacts of trade conflicts. Production capacity of crystalline Si cell in Vietnam in 2017 is more than 2 GW/year.

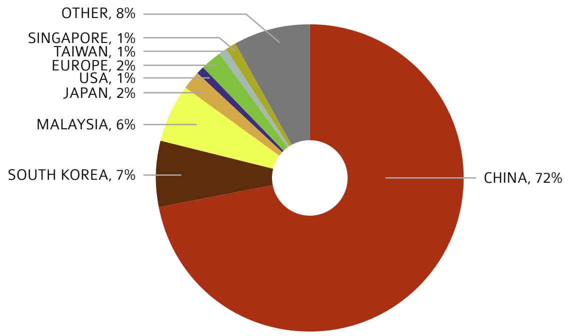
Figure 19 shows the evolution of solar cell production volume of selected countries. China continued to produce the largest number of cells in the world. Taiwan ranked second just as in 2016, and produced approximately 12 GW. Malaysia and South Korea showed notable increases in solar cell production. Malaysia produced nearly 7 GW of solar cells (crystalline Si and CdTe) with about 8 GW/year of production capacity. Malaysia hosts factories of major manufacturers including JinkoSolar (China), LONGi Green Energy Technology (China), Hanwha Q Cells (South Korea), JA Solar (China), COMTEC (China), SunPower (USA), First Solar (USA), and Panasonic (Japan). The growth in South Korea was mainly attributed to investment in increasing production capacity by Hanwha Q Cells.

FIGURE 17: SHARE OF PV CELLS PRODUCTION IN 2017



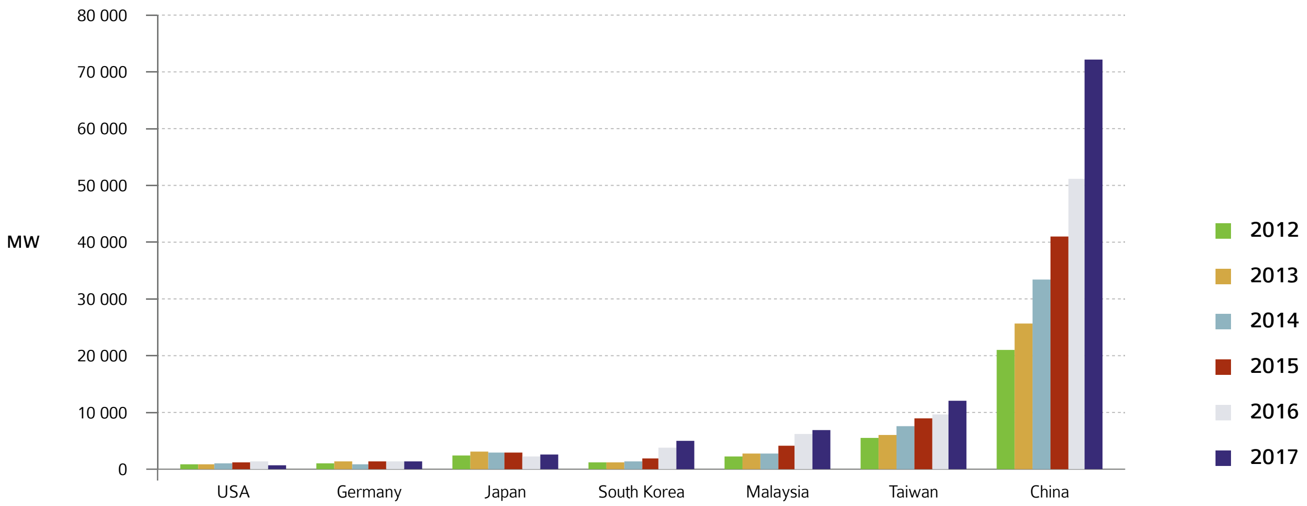
SOURCE IEA PVPS, RTS CORPORATION.

FIGURE 18: SHARE OF PV MODULE PRODUCTION IN 2017



SOURCE IEA PVPS, RTS CORPORATION.

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



SOURCE IEA PVPS, RTS CORPORATION.

For crystalline Si solar cells, demand for high efficiency cells is increasing, and the share of sc-Si solar cells increased in 2017. For sc-Si wafers, manufacturers are also expanding their production capacity. Recently, the demand for sc-Si PV products is increasing due to high generation efficiency and price reduction, as well as the Top Runner Program in China. As a result, the share of mc-Si PV cell decreased to 68% in 2017 compared to about 76% in 2016. As mentioned in the 2016 edition of this report, major manufacturing companies are shifting their production lines to PERC solar cells. The share of PERC solar cells is expected to have reached 25% by the end of 2017 while the share as of the end of 2016 was approximately 15%.

Major PV manufacturers reported updates of conversion efficiency of PERC solar cells one after another. In February 2018, LONGi Green Energy (China) reported to have achieved conversion efficiency of 23,6% on sc-Si PERC solar cell. Conversion efficiency of p-type mc-Si PERC solar cell is improving as well, and JinkoSolar (China) reported to have achieved 22,04% in October 2017.

The introduction of bifacial cells is progressing since the structure of PERC solar cell makes it easy for bifacial power generation. Major PV manufacturers are continuously investing in improvement of efficiency, and is aiming to improve efficiency through improved passivation process for PERC or PERT structures, thinner electrodes, adoption of 4 or more bus bars (4 is the standard, 5 and 6 bus bar products are also released on the market), and adoption of wiring with multi-bus bars or no bus bars.

Global PV module production (crystalline silicon PV module and thin-film PV module) is estimated to be about 105 GW in 2017. More than 90% of PV modules were produced in IEA PVPS member countries.

THE UPSTREAM PV SECTOR / CONTINUED

As shown in Figure 18, China is the largest PV module producing country that produced 75 GW of PV modules in 2017, accounting for 72% of global PV module production,an increase of 2,1 percentage points on a year-on-year basis. In terms of product type, almost all products were crystalline silicon PV module, and the output of thin film PV module was less than 200 MW.

Following China, the second position in module producing country is South Korea, which produced about 7,7 GW. Malaysia ranked third with about 6 GW of production. Other major IEA PVPS countries that reported PV module production capacity are mainly Japan, Germany, and USA. Australia, Austria, Belgium, Canada, Mexico, Denmark, France, Italy, Finland, Sweden, Thailand, Turkey, and South Africa also possess PV module production capacity.

In 2017, JinkoSolar shipped the world's highest volume of PV modules, 9,8 GW. JinkoSolar owns production facilities in China and Malaysia with 8 GW/year PV module production capacity as of the end of 2017, and also utilizes OEM production. Trina Solar ranked second with about 9 GW of shipment. The company also owns production bases in other countries such as Thailand and Vietnam. JA Solar (7,3 GW), Canadian Solar (6,9 GW) and Hanwha Q Cells followed.

Similar to last year, major Chinese companies established manufacturing factories outside of China such as in Turkey, Malaysia, Thailand, Vietnam and Brazil in order to avoid anti-dumping duties (ADs) implemented under trade conflicts or just to meet domestic content requirements (DCR). In 2017, BYD, China started to operate a 200 MW/year PV module factory in Brazil. Chint Solar is also planning to establish a PV module factory there. As a result, PV module production bases are becoming more and more diversified.

Among non IEA PVPS members, major countries producing PV modules are Singapore, Taiwan, Philippines, Vietnam, India, and Poland. Production bases have been established in Algeria, Brazil, Morocco, Ghana, Saudi Arabia, Indonesia, and so on. In India, it is assumed that more than 100 manufacturing companies exist and the total manufacturing capacity is more than 8 GW/year. However, only some of the facilities are actually operating. Due to trade friction and its government's policy to establish domestic manufacturing capacity, news of enhancement or new construction PV modules lines are announced from both domestic and overseas manufacturers. In the end of 2017, Vietnam has at least 2,5 GW of PV module manufacturing capacity and according to the expansion plan announced it will have more than 8 GW/year if all of the announced plan would be realized in the future.

Reflecting the improvement of solar cell efficiency, the output of PV modules is also increasing. Higher wattage PV modules have been released using high efficiency solar cells as well as half-cut solar cells. Other technologies such as light trapping with glass coatings, encapsulants with wavelength conversion functions are also contributing to improvement of conversion efficiency. PV modules using overlapped solar cells without ribbons are developed by several companies. Other new products include double glass PV modules with 30-year warranties or using bifacial PV modules to gain more yield, PV modules for 1 500 V connection, light weight c-Si PV modules using chemical tempered glass or polymer. BIPV modules utilizing coating of surface glass and colored films are also being proposed.

The average spot price of PV modules in the beginning of 2017 was 36 USDcents/W and gradually decreased to 31 USDcents/W by the end of the year. This is the result of expansion of production capacity exceeding the increased demand. This situation is giving a negative impact on the profit structure of major PV module manufacturers, and there are concerns over the sustainability of PV module manufacturers. In 2018, it is highly likely that the global PV installed capacity will decrease year on year due to the changes in China's policy. Thus, the reduction of PV module price is further progressing, and consolidation of PV module manufacturers are expected to accelerate.

Figure 20 shows the trends of estimated global PV module production capacity and production volume. Estimated global PV module production capacity increased from 105 GW in 2016 to 133 GW in 2017. The largest increase of production capacity was reported by China. According to the Chinese Photovoltaic Industry Association (CPIA), China's domestic PV module production capacity increased from 79 GW/year in 2016 to 105,4 GW/year in 2017.

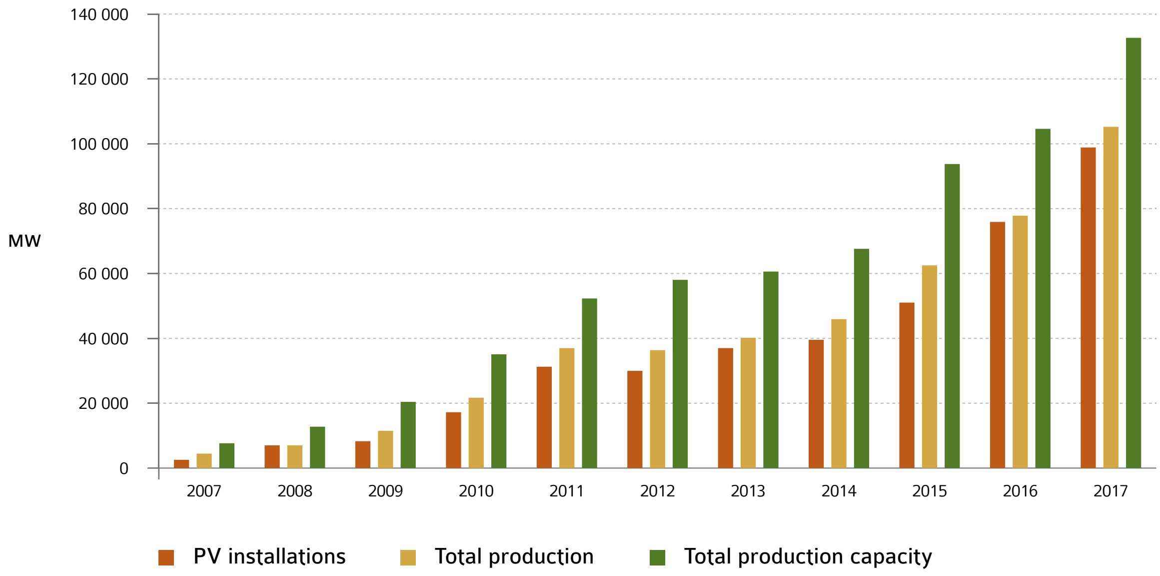
The utilization rate in 2017 was 79%, a 6% increase from the previous year, reflecting the growth of PV installed capacity. Enhancement of manufacturing capacity is realized not only by the construction of new factories but also by acquisition of closed factories or establishing joint ventures with other companies. Furthermore, in order to secure production bases overseas, establishment of joint ventures, as well as capital investment and acquisition of local businesses are being conducted. In addition, improvement of conversion efficiency contributed to enhancement of production capacity.

It is estimated that 3,3 GW of thin film PV modules were produced in 2017, accounting for about 3% of total PV module production (see Figure 21). Thin-film PV modules are mainly produced in Malaysia, Japan, USA, Germany and Italy as they were in the previous year. First Solar of USA remained the world's largest thin-film PV module manufacturer. It reported that it produced 2 084 MW of CdTe thin-film PV modules in its factories in the USA and Malaysia in 2017, and shipped 2,7 GW. It ranked tenth in the global PV module production, and was the only thin-film PV module manufacturer ranked in the top 10. The company is constructing a factory in Vietnam with the production capacity of 1,2 GW/year, which is planned to start operation within 2018. First Solar also announced a plan to expand production capacity by 1,2 GW/year in Vietnam.

The world's second largest thin-film PV manufacturer in 2017 is Solar Frontier of Japan. It produced 690 MW of CIS thin-film PV modules in 2017. Other thin-film PV manufacturing activities were reported from USA, Germany, Italy, Switzerland, etc.

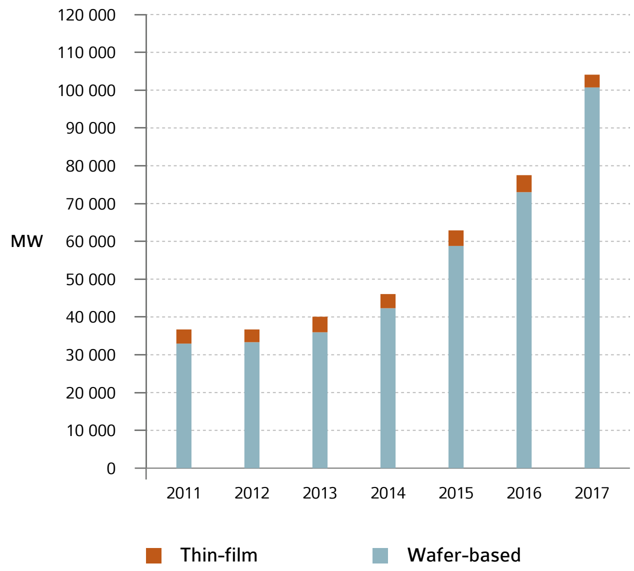
For thin-film PV, new production bases are being established in China: Hanergy as well as China National Building Materials (CNBM) are constructing production facilities. In January 2017, Hanergy started production of flexible CIGS thin-film PV modules in Hubei Province, China using technology developed by US MiaSole. The

FIGURE 20: YEARLY PV INSTALLATION, PV PRODUCTION AND PRODUCTION CAPACITY 2007-2017 (MW)



SOURCE IEA PVPS, RTS CORPORATION.

FIGURE 21: PV MODULE PRODUCTION PER TECHNOLOGY IN IEA PVPS COUNTRIES 2011-2017 (MW)



SOURCE IEA PVPS, RTS CORPORATION.

company also made an agreement with a local government in Shanxi Province in China and Dong Coal Mine Group to establish 300 MW/year factory of CIGS PV modules.CNBM launched construction of CIGS PV module factory in Sichuan Province in China aiming at establishing 1GW/year production capacity in June 2017.

Efforts on R&D and commercialization of thin-film PV modules are continuously reported in a number of IEA PVPS member countries aiming for improvement of conversion efficiency and throughput, as well as enlargement of the size of PV modules.

To compete with CdTe technology, First Solar decided to introduce large-sized CdTe thin-film PV modules earlier than the original plan. While the company was planning to release a new product with an output capacity of 365 W (S5 series) in 2017, it decided to progress development of larger-sized next generation PV modules (S6 series) ahead of schedule, and is shifting the production facilities. As for thin-film PV, PV modules utilizing flexible substrate that can be applied on curved surfaces, light transmission type PV modules with higher transparency, and roof tile-integrated PV modules for BIPV are being proposed.

In 2017, 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, the cPV system seems to be less cost competitive and has difficulties competing with conventional PV systems. Due to the withdrawal of several cPV companies from the business, most activities related to cPV technologies shifted back to R&D and Demonstrators.

THE DOWNSTREAM SECTOR

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

PV developers have been active in PV power plant developments in the countries where power purchase agreements (PPAs) are guaranteed or feed-in tariff programs are implemented. While developers sell PV power plants to Independent Power Producers (IPPs) or investors, some developers own PV power plants as their own assets. Companies providing Engineering, Procurement and Construction for PV systems (mainly utility-scale applications but larger commercial or industrial applications also fall into this category) are called EPCs. EPCs include pure-player 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 plants and own them, while others provide EPC and own PV power plants as well, until they sell the PV power plants to IPPs. Generally, utility-scale projects are owned by IPPs (together with equity investors), who sell the power to utilities under a long-term PPA. Equity investors or other financial institutes also play an important role for the PV project development as equity or loan providers.

Companies doing business in the downstream sector have various origins: subsidiaries of utility companies, subsidiaries of PV module or polysilicon manufacturers, companies involved in the conventional energy or oil-related energy business. Major PV project developers are enhancing overseas deployment and are active in business deployment in Africa, the Middle East and Latin America. The number of developers deploying international business is increasing. Just as the previous year, 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 expanding their business in the PV and other renewable sectors.

These companies are expanding investments in the PV business, establishing subsidiaries for PV project development and are active in acquisition. Innogy (Germany), a subsidiary of RWE engaged in the renewable energy business, acquired BELECTRIC Solar & Battery, a subsidiary of Belectric (Germany) in January 2017 to enhance the PV business. Total (France) announced its plan to acquire 23% stake of Eren RE (France) for 237,5 MEUR.

Asian utility companies are also active in the renewable energy business. The Malaysian national electric power company, TENAGA

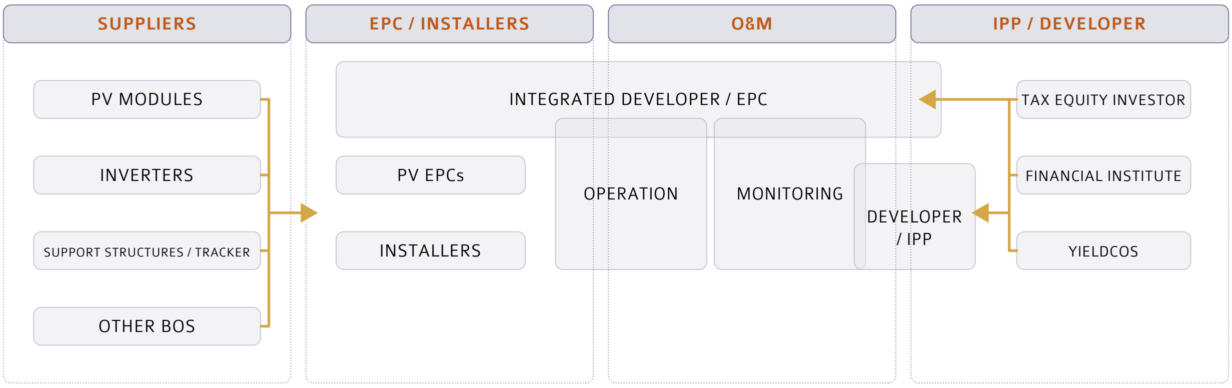
TABLE 5: EVOLUTION OF ACTUAL MODULE PRODUCTION AND PRODUCTION CAPACITIES (MW)

	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	67%
2017	97 942	7 200	105 142	122 800	10 250	133 050	79%

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

SOURCE IEA PVPS & OTHERS.

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



SOURCE IEA PVPS & OTHERS.

NATIONAL, developed utility-scale PV projects in Malaysia and participated in a bidding held in the Middle East. KEPCO, the South Korean national electric power company is actively investing in PV projects in Japan, Mongolia, USA, etc. KEPCO announced that it started a test operation of a 28 MW PV power plant integrated with a 13,7 MWh storage system in Chitose City of Hokkaido, Japan. In addition, the company participated in tenders held in Ethiopia and Armenia in 2018 in the form of a consortium with private companies.

It is also noted that several integrated companies are present in the downstream sector. These companies produce PV modules or polysilicon, develop PV projects, and provide EPC/ O&M services. Thin-film PV module manufacturer First Solar and c-Si PV module manufacturers such as JinkoSolar, Canadian Solar, SunPower and Hanwha Q CELLS are active in the downstream sector.

Notable polysilicon manufacturers investing in the international downstream business are GCL-Poly Energy in China and OCI in South Korea. GCL New Energy, a subsidiary of GCL-Poly Energy in China achieved the cumulative PV system installed capacity of 5 GW and was reported to have ranked second globally in terms of cumulative PV installed capacity. OCI Global, an OCI subsidiary targeted to develop PV projects in the USA and has a plan to invest in more than 1 GW of PV projects in China and India by 2018.

Companies engaged in PV project development are also active in the field of battery storage. SunPower Corporation announced that it would install a 5 MW PV system and a 500 kW storage system at the University of California, Merced (USA). A US solar farm developer Cypress Creek Renewables, in collaboration with United Renewable Energy is co-developing a series of 12 solar-plus-storage projects (combined storage capacity of 12 MWh) with Brunswick Electric Membership Corporation (EMC) in North Carolina. Tesla announced that it received an order from the world's largest 129 MWh lithium ion battery storage project in South Australia, Australia.

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 ownership (TPO) business models are quite active. The companies using the TPO business model provide PV systems to property owners and sign an agreement to supply PV electricity generally at a lower price than the retail electricity price. The major examples of TPO companies active in the USA are Sunrun, Tesla, Vivint Solar, etc. These companies also provide loans to customers who want to keep the ownership of PV systems.

Services applying off-grid PV systems for non-electrified areas in Africa and other nations are also active. The small-scale off-grid PV system business is active, through divided payment of handling charge and usage fee called pay-as-you-go (PAYG) schemes, as well as rental with purchase options. Azuri Technologies (UK), BBOXX (UK) and SolarHOME (Singapore), etc., are representative examples of such cases. Some of these companies develop PV projects through crowd funding.

BALANCE OF SYSTEM COMPONENT MANUFACTURERS AND SUPPLIERS

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

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, the PV power 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 such as China, Japan, South Korea, Australia, the USA, Canada,

DOWNSTREAM SECTOR / CONTINUED

Germany, Spain, Austria, Switzerland, Denmark, Italy and Thailand. 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 67 GW in 2017, a 68% growth from the previous year, of which 12 GW was exported. It is estimated that Chinese manufacturers' share in the global PV inverter market was around 66%. While in 2011, China counted only one inverter manufacturer in the top 10 (Sungrow), in 2017, five Chinese companies ranked into the top 10 in the shipment volume segment (Huawei (No.1), Sungrow (No.2), Sineng (No.4), and TBEA Sun Oasis (No.5)).

The products dedicated to the residential PV market have typical powers ranging from 1 kW to 10 kW, for single (Europe) or split phase (the USA and Japan) grid-connection. For utility-scale applications, 2 to 3 MW centralized inverters are common. 5 MW inverters are also available. The share of string inverters is increasing for large-scale PV systems. According to GTM Research, 46,2 GW of three-phase inverters were shipped in 2017, which exceeded the shipment of centralized inverters (42,4 GW) for the first time.

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. An increasing number of manufacturers offer inverter and PV storage solutions for the market where self-consumption is the 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. MLPE can help in achieving a higher output for PV arrays with shading and has been proven more effective for a rapid shutdown in case of fire. It is estimated that about 3,6 GW of these devices were shipped in 2017.

As well as for PV module suppliers, inverter manufacturers have been suffering from significant cost pressures and tighter competition. The consolidation of manufacturers is still underway and players need to differentiate 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. Around 60% of existing 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 interest in storage batteries is growing with the development of self-consumption business models and tighter codes for building energy efficiency. In the markets that already achieved a rather high penetration of PV (California, Hawaii, Australia, etc.), the demand for battery storage for PV systems is increasing. However, such batteries are still expensive without subsidies. Utility-scale storage projects have also been reported in the regions where PV penetration is growing rapidly.

TRADE CONFLICTS

Trade conflicts over PV products including polysilicon continued to give impacts on business strategies of PV companies. To avoid the imposition of tariffs in several countries on different types of products, PV module manufacturers announced new production enhancement plans in Malaysia, Thailand, India and some countries in Europe. In this section, trends of major trade conflicts observed in 2017 are described.

A new issue emerged in the USA in 2017. Suniva, a bankrupt US PV cell/module manufacturer filed a petition to the International Trade Commission (ITC) under the US Department of Commerce (DOC) with SolarWorld Americas, claiming that a serious damage was caused by imported solar cells and modules, and requesting for the implementation of safeguard measures under the Section 201 of the US Trade Act of 1974. ITC started investigation in May 2017 and concluded that the US PV manufacturers were damaged by imported crystalline silicon (c-Si) PV products. Finally, on February 7, 2018, the US President Donald Trump announced implementation of safeguard measures under the Section 201, which is effective for four years. Tariffs imposed on c-Si solar cells and modules are 30% in the first year, 25% in the second year, 20% in the third year and 15% in the fourth year. As for solar cells, however, tariffs will be exempt for up to 2,5 GW/year of import. Following this announcement, China released a comment criticizing the US decision. South Korea announced that it plans to file a petition with the World Trade Organization (WTO), whereas Mexico indicated that it will possibly take legal measures to request the US to comply with the North American Free Trade Agreement (NAFTA). With the implementation of safeguard measures, the prices of c-Si PV modules imported to the US are expected to increase, which indicates that the utility-scale PV market will particularly be impacted. However, the US utility-scale PV power plants are below 10 GW and it is assumed that the impacts on the global supply and demand balance will not be so serious. Furthermore, major PV manufacturers are planning or considering to set up manufacturing bases in the USA.

In Europe, the European Commission (EC) and the Chinese PV industry continued to implement an agreement on minimum import price (MIP) and maximum shipping volume. For the companies which do not join the agreement, antidumping duties (AD) and countervailing duties (CVDs) will be imposed on their PV products. In February 2017, the EC decided to extend the agreement by 18 months and announced that duty margins and MIP would be gradually decreased following the cost reduction trends of PV products. Back in February 2016, EC announced it would apply ADs and CVDs to Chinese PV modules imported via Taiwan and Malaysia. Some major PV module manufacturers voluntarily decided to withdraw from the agreement because the MIP did not reflect actual trends of market price. Many of these manufacturers established their production facilities outside of China. In July 2017, DG Trade of

EC announced a draft proposal for the procedures to set MIP on a quarterly basis. Since a number of Chinese companies withdrew from the MIP agreement or start of production in the areas other than those subject to duties, the effectiveness of MIP has been questioned. In August 2018, the European Union (EU) decided to terminate AD and CVD measures on c-Si PV cells and modules, which were implemented in 2013. AD and CVD measures as well as MIP agreement was ended. EU made an official announcement in the official gazette on September 3, 2018.

The Turkish government decided to impose of ADs on Chinese PV modules in April 2017. The committee responsible for the investigation set the dumping margin of 27%. The actual duty was imposed by every square meter of PV module, 20 USD/m² for some companies and 25 USD/m² for others. It was analyzed that the PV module price in Turkey will increase by 30 to 35%. Meanwhile, in the beginning of 2017, with a plan to enhance PV production capacity, the Turkish Ministry of Energy and Natural Resources conducted a tender for a 1-GW PV project in Karapinar, Turkey. The tender requires the tender winner to build a PV module manufacturing facility with a production capacity of 500 MW/year or more in addition to domestic content requirements (DCR). Hanwha Q-Cells of South Korea won the tender, jointly with a Turkish company Kalyon Enerji.

In 2017, a trade conflict emerged in India as well. In July 2017, Indian Directorate General of Anti-Dumping and Allied Duties (DGAD) under the Department of Commerce (DOC) initiated an antidumping investigation following the petition submitted by the Indian Solar Manufacturers Association (ISMA). Subjects for the investigation are PV cells and modules produced in China, Malaysia and Taiwan. While it is expected that the investigation will take more than a year, preliminary results, safeguard investigation was started in December 2017. The Indian Ministry of Commerce initiated investigation on PV products (c-Si PV cells and modules as well as thin-film PV cells and modules) that were imported into India, in response to the request by ISMA. Afterwards, the Ministry of Commerce decided to impose a 25% safeguard tariff on PV cells and modules imported from Malaysia and China and enforced it on July 30, 2018. The safeguard measures are based on the proposal by the Directorate General of Trade Remedies (DGTR), and the tariffs are 25% in the first year, 20% in the first six months of the second year (5% reduction), and 15% in the last six months of the second year (another 5% reduction), and will be applied for two years. The tariffs will be applied to China and Malaysia, and all the other developing countries are excluded. However, on August 13, 2018, India's Ministry of Finance announced postponement of implementing safeguard measures, following the ruling by the Orissa High Court. Earlier, before the announcement on implementation by the Ministry of Finance at the end of July 2018, the Orissa High Court, in response to the petition by ACME Solar, India's largest PV project developer, requested that safeguard measures should not be implemented before August 20, 2018. Despite this request, the Ministry of Finance implemented the safeguard tariff, and ACME Solar as well as other major power producers Hero Future Energies and Vikram Solar, engaging in PV cell/ module manufacturing and EPC business, claimed that the safeguard tariff is invalid. As a result, the High Court requested the Finance Ministry to withdraw the tariff by August 13. The High Court held a hearing on August 27 and announced that it will hold another hearing on September 19, 2018. As of the end of August 2018, whether or not the safeguard measures will be implemented, and the timing if they will be implemented are uncertain. It was reported that, in case the safeguard measures will be implemented officially, the safeguard tariff will be retroactively imposed on the products that cleared the customs on and after July 30, 2018. Furthermore, India has been implementing duties on materials of solar cells to protect the domestic industry. In August 2017, India's Ministry of Finance decided to impose AD on made-in-China tempered glass for PV modules for five years. The duties are 52,85 USD/t for Xinyi PV Products (China) and Xinyi Solar (Hong Kong), 64,04 to 97,63 USD/t for three other companies, and 136,21 USD/t for others. DGAD also announced that it would hold a hearing in July 2018 on an anti-dumping investigation on EVA used as encapsulant for PV modules, manufactured in China, Malaysia, South Korea, Thailand and Saudi Arabia. It has officially launched the investigation in April 2018.

In 2016, China decided an 18 months extension of ADs and CVDs on polysilicon made in the USA and Europe, as well as ADs on Korean-made polysilicon which have been imposed since May 2014. Mainly the US manufactures are affected by the ADs and CVDs while Korean manufacturers can continue to export their products with lower ADs. In November 2016, the Chinese Ministry of Commerce announced that it would review duty margins for polysilicon made in South Korea. Wacker Chemie, a German polysilicon manufacturer avoids AD by the agreement on the price with the Chinese government. REC Silicon of Norway that has manufacturing bases in the USA announced that it established a joint venture with a Chinese company to construct a FBR process-based polysilicon factory in China. In May 2017, the Chinese Ministry of Commerce decided upon an 18-month extension of ADs and CVDs on polysilicon made in Europe. The ADs and CVDs had been imposed for two years since May 1, 2014. The first extension was decided in April 2016 and expiration date was set on April 30, 2016. In February 2016, Chinese polysilicon manufacturers requested the extension of ADs and CVDs, and it was decided that they would be extended by 18 months from May 1, 2017. In March 2018, the Commerce Ministry announced that the imposition of ADs and CVDs on European polysilicon are planned to be terminated on October 31, 2018. If additional request for extension would be applied, examination would be conducted. Reportedly, the Chinese polysilicon manufacturers are planning to request for the re-examination. The Chinese manufacturers are announcing plans for the enhancement of production capacity. GCL-Poly Energy will transfer its factory in Xuzhou, Jiangsu Province to Xinjiang Uygur Autonomous Region and increase the production capacity. GCL-Poly will not only transfer the 20 000 t/year factory and its facilities in Xuzhou, but will also expand the polysilicon production capacity of the factory from 40 000 t/year to 60 000 t/year in total. This is assumed to be a part of the company's business strategy to ensure competitiveness through transferring a manufacturing base to a place where electricity charges are low.

TRENDS IN PHOTOVOLTAIC APPLICATIONS // 2018

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME WWW.IEA-PVPS.ORG

TOTAL BUSINESS VALUE IN PV SECTOR IN 2017

$110 BILLION

TOP 5 PV MARKETS IN 2017

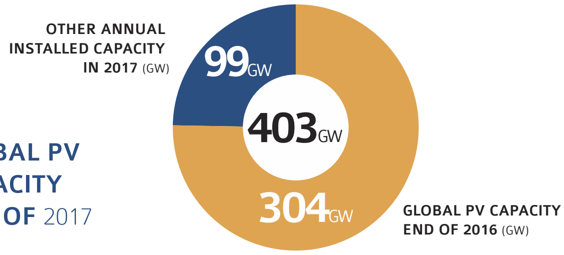
- CHINA 53,1 GW
- USA 10,7 GW
- INDIA 9,1 GW
- JAPAN 7,5 GW
- TURKEY 2,6 GW

PV CONTRIBUTION TO ELECTRICITY DEMAND

2,5 %

Share of PV in the global electricitiy demand in 2017

GLOBAL PV CAPACITY END OF 2017



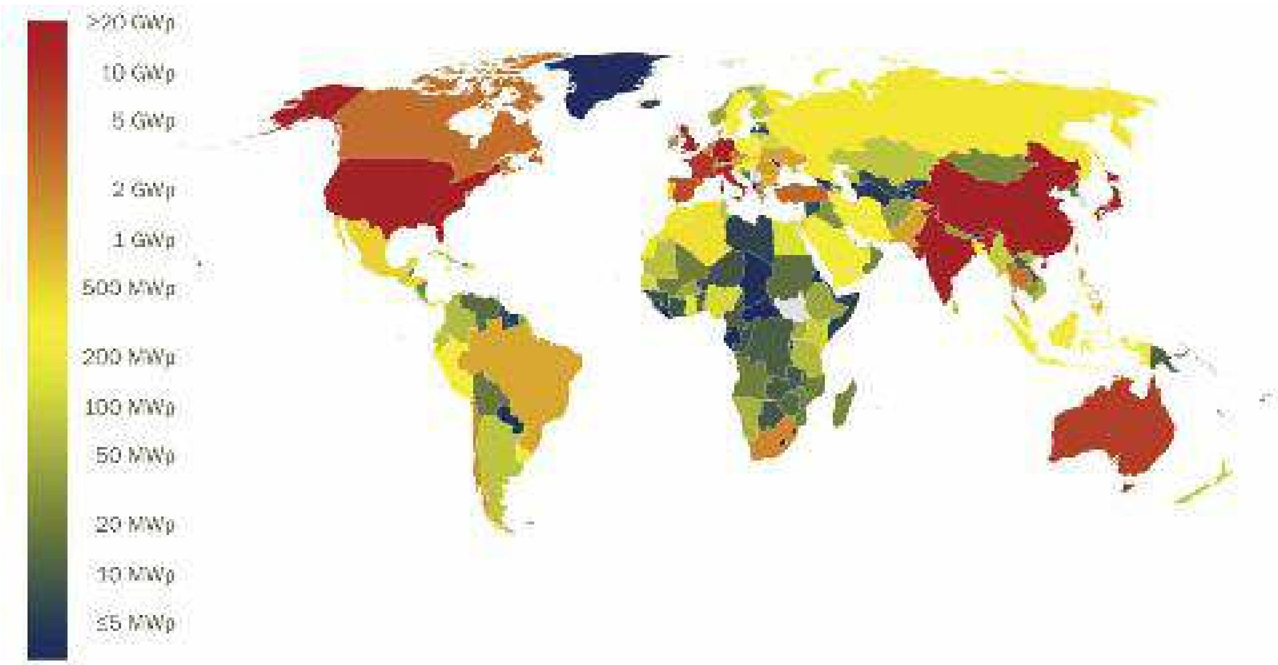
CLIMATE CHANGE IMPACTS

247 millions of tons of CO_2 **saving** every year,

equivalent to taking **140** million cars off the road

or planting **164** million trees each year

GLOBAL CUMULATIVE PHOTOVOLTAIC SOLAR POWER BY THE END OF 2017



27 COUNTRIES REACHED AT LEAST **1 GWp** IN 2017

PV POWER PER CAPITA

1. GERMANY (514 Wp)
2. JAPAN (390 Wp)
3. BELGIUM (341 Wp)

9 COUNTRIES INSTALLED AT LEAST **1 GWp** IN 2017

SOURCE CH. WERNER, A. GERLACH, CH. BREYER, G. MASSON. 2018. GROWTH REGIONS IN PHOTOVOLTAICS 2017 UPDATE ON LATEST GLOBAL SOLAR MARKET DEVELOPMENT

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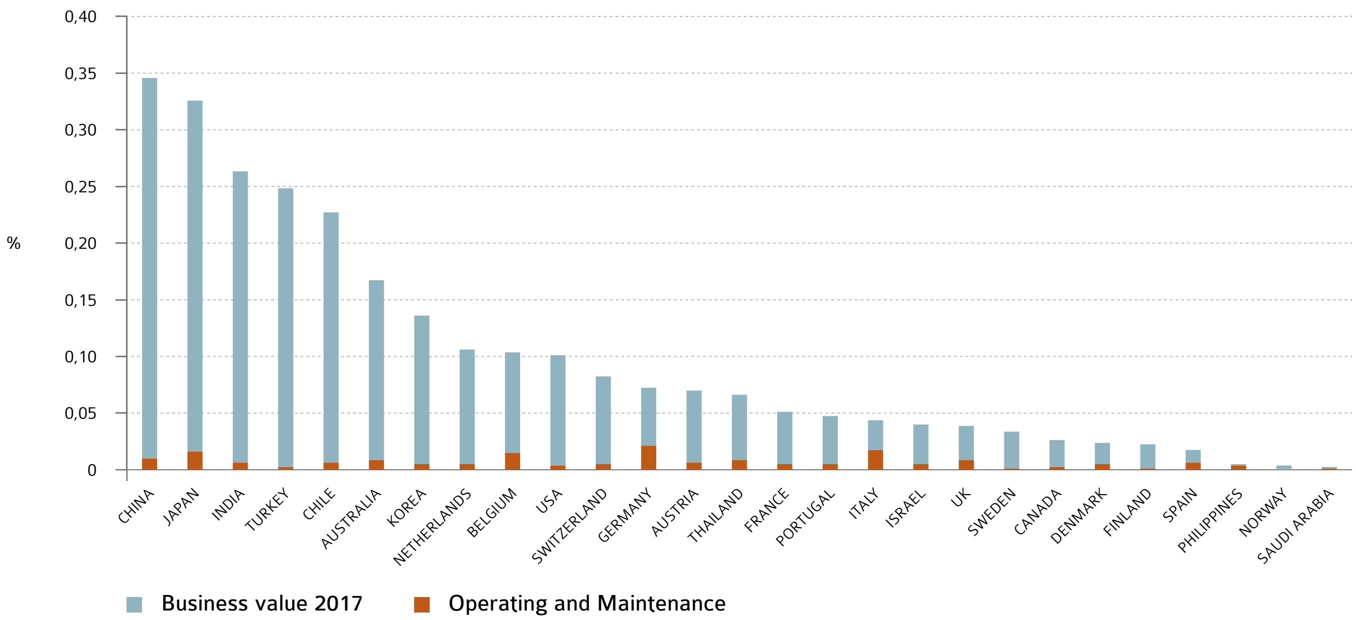
PV AND THE ECONOMY

VALUE FOR THE ECONOMY

The 30% growth of the PV installed capacity between 2016 and 2017 combined with the strong decline in prices, especially for utility-scale plants caused the business value of PV to stay quite stable around **110 Billion USD**. The value of O&M has increased slightly to 5,2 Billion USD while the growth of the market hasn't produced a dramatic increase on the installation side.

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 including Operation and Maintenance.

FIGURE 23: BUSINESS VALUE OF THE PV MARKET COMPARED TO GDP IN % IN 2017



SOURCE IEA PVPS & OTHERS.

VALUE FOR THE ECONOMY / CONTINUED

CONTRIBUTION TO THE GDP

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. However, the market is integrated to the point that it would be extremely complex to assess the contribution from each part of the PV value chain. With european and asian equipments, tier-1 companies are producing in different places, buying components and materials all over the world.

The business value of PV represented less than 0,4% in all countries considered and more than 0,05% in most of them. In India and China the business value of PV corresponds to around 0,35% of the country GDP. Turkey is following with 0,32% while the PV business value in Japan dropped to 0,25% with respect to the 0,36% in 2016 and 0,50% in 2015. Australia and Chile registered A PV business value close to 0,20% of their GDP. USA, Korea, Belgium, Switzerland, Thailand, Austria, France and Germany are located between 0,05% and 0,10%.

The business value of the industry is in general more complex to assess, due to decentralized production and transnational companies. In this respect it is not considered here.

O&M

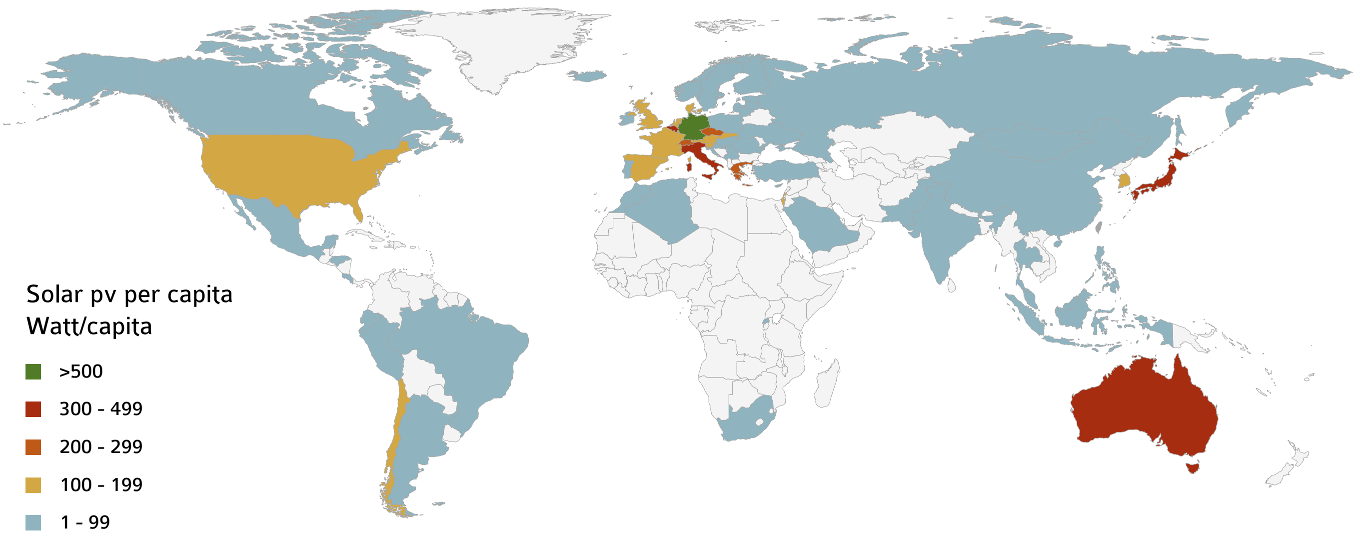
The turnover linked to Operation and Maintenance is not considered in detail, given the variety of existing maintenance contracts and costs. Although, one might estimate the global turnover related to O&M in the PV sector around 5,2 BUSD per year depending on assumptions. In the figure above, the O&M contribution to the business value has been estimated based on the lowest assumptions.

INSTALLED CAPACITY PER INHABITANT

Figure 24 shows the PV capacity across reporting countries per inhabitants in 2017, in Watts/capita.

Germany had the highest capacity per inhabitant by a large margin, at 514 Watts/capita. Japan had a capacity of 390 Watts/capita, followed by Belgium (341 Watts/capita) and Italy (325 Watts/capita). Australia comes next with 297 Watts per capita, followed by Greece, Malta, Switzerland and Czech Republic by a large margin with respect to UK that ranks significantly below with 192 Watts/capita.

FIGURE 24: PV PENETRATION PER CAPITA IN 2017



SOURCE IEA PVPS & OTHERS.

TRENDS IN EMPLOYMENT

Employment trends in the PV sector should be considered in various fields of activity, i.e. research and development, manufacturing including equipment, but also deployment, maintenance and education. However, these activities are significantly diverse and the job creation is driven by different key factors in each of these fields.

Employment dynamics in the PV sector are evolving in line with the changes in the PV markets and industry. PV labour place trends reflect the status of the PV Industry landscape development and how the supply chain is becoming more globalised and geographically differentiated.

With 99 GW installed during 2017, the solar PV industry experienced a significant growth in global employment. According to the assumptions and the field of activities considered, China is markedly leading the market with more than 2,5 million jobs in 2017, followed by Japan with around 0,1 million and the USA (that recorded the first decline in PV employment), while the European Union continued its downward slide. The decrease of the market in several key European countries has quickly pushed the installation jobs down while some other countries, where the market is growing, experienced an opposite trend, especially in Asia.

The emergence of PV as a mainstream technology wakes up the appetites for local manufacturing and job creation at all levels of the value chain. Looking at IEA PVPS member countries only, several countries have pushed through different schemes for local manufacturing and especially Canada, France, Morocco, Turkey or the USA. Other countries have succeeded in bringing many manufacturers to produce PV components in their country, such as Malaysia which is the most successful example to date. Other like Chile or South Africa are eyeing possibilities.

In general, it remains difficult to estimate precisely the number of jobs created in relation to the development of PV: part of workplace (direct and indirect) stands either in the upstream or downstream sectors of the value chain, mixed with others. The National Survey Reports detail jobs in most countries participating to the IEA PVPS programme.

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COMPETITIVENESS OF PV ELECTRICITY IN 2017

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.

However, the question of competitiveness should be always contemplated in comparison with the other technologies. Energy has always been considered in the last two centuries as a business unlike the other ones. The fast development of nuclear in some countries in the last 40 years is a perfect example of policy-driven investments, where governments imposed the way to go, rather than letting the market decide. The oil and gas markets are also perfect examples of policy-driven energies which are deemed to important not to be controlled. PV competitiveness should therefore be considered in that respective, rather than the simple idea that it should be considered competitiveness without any regulatory or financial support. Since all sources of electricity have benefited at some point from such support, the question of the competitiveness of PV should be considered carefully. Hereunder, we will look at the key elements driving the competitiveness of PV solutions.

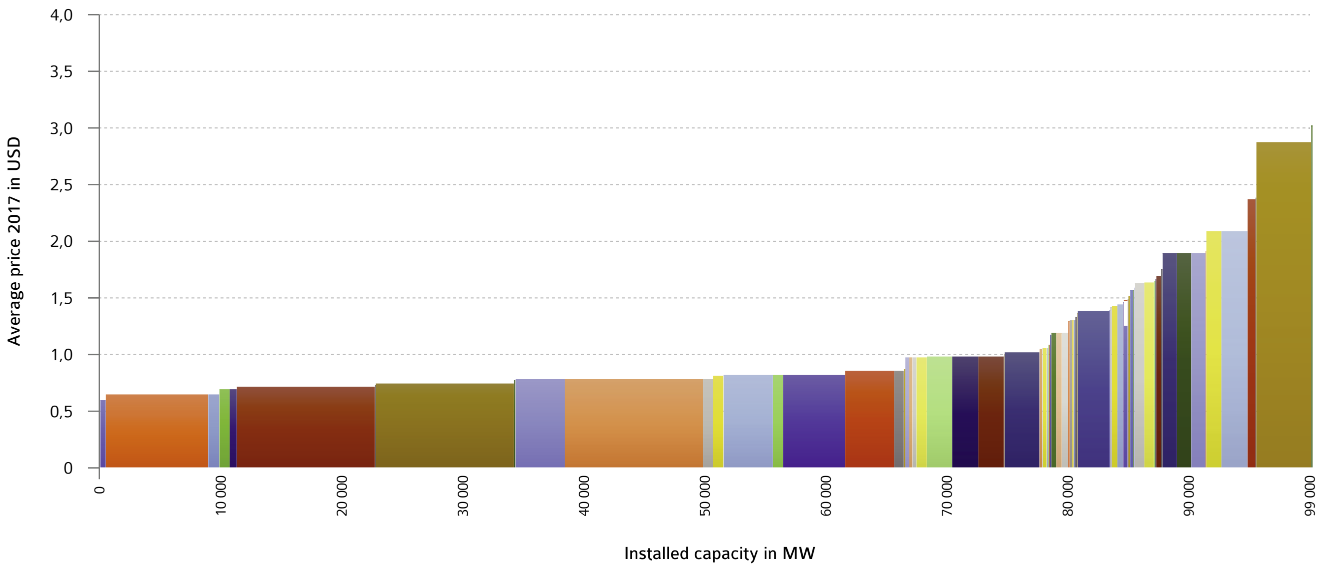
SYSTEM PRICES

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. For more detailed information, the reader is directed to each country's national survey report at www.iea-pvps.org.

Figure 25 shows the range of system prices in the global PV market in 2017. It shows that half of the PV market consists in prices below 0,8 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.

FIGURE 25: 2017 PV MARKET COSTS RANGES



SOURCE IEA PVPS & OTHERS.

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 2017, the lowest system prices in the off-grid sector, irrespective of the type of application, typically ranged from about 1,17 USD/W to 14,65 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 2017 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 down in 2017, 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 0,70 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 2017 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 2017.

SYSTEM PRICES / CONTINUED

TABLE 6: INDICATIVE INSTALLED SYSTEM PRICES IN SELECTED IEA PVPS REPORTING COUNTRIES IN 2017

	GRID-CONNECTED (LOCAL CURRENCY OR USD PER W)								OFF-GRID (LOCAL CURRENCY OR USD PER W)			
	RESIDENTIAL		COMMERCIAL		INDUSTRIAL		GROUND-MOUNTED		<1 kW		>1 kW	
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	2,22	1,63	2,01	1,48	NA	NA	2,24	1,65	NA	NA	NA	NA
AUSTRIA	1,62	1,76	1,19	1,29	NA	NA	NA	NA	5,00	5,42	NA	NA
BELGIUM	1,2 - 1,7	1,3 - 1,84	1,1 - 1,2	1,19 - 1,3	0,85 - 1,1	0,92 - 1,19	NA	NA	NA	NA	NA	NA
CANADA	2,5 - 3,2	1,85 - 2,37	2 - 2,5	1,48 - 1,85	1,8 - 2	1,33 - 1,48	1,80	1,33	NA	NA	NA	NA
CHINA	5,5 - 6	0,78 - 0,85	5,5 - 6	0,78 - 0,85	5,5 - 6	0,78 - 0,85	5 - 5,5	0,71 - 0,78	NA	NA	NA	NA
DENMARK	7 - 13	1,02 - 1,89	6 - 12	0,87 - 1,75	6 - 13	0,87 - 1,89	3 - 7	0,44 - 1,02	8 - 22	1,17 - 3,21	NA	NA
FRANCE	1,9 - 2,6	2,06 - 2,82	1,20	1,30	0,90	0,98	0,8 - 1	0,87 - 1,08	NA	NA	NA	NA
FINLAND	1,2 - 1,8	1,3 - 1,95	0,9 - 1,15	0,98 - 1,25	0,85 - 1,15	0,92 - 1,25	0,9 - 1,1	0,98 - 1,19	5,00	5,42	NA	NA
GERMANY	1,13 - 1,58	1,22 - 1,71	0,85 - 1,35	0,92 - 1,46	0,98	1,06	0,92	0,99	NA	NA	NA	NA
ISRAEL	5 - 6	1,33 - 1,6	3,5 - 3,8	0,93 - 1,01	3 - 3,2	0,8 - 0,85	2,6 - 2,77	0,69 - 0,74	NA	NA	NA	NA
ITALY	1,2 - 1,6	1,3 - 1,73	1 - 1,4	1,08 - 1,52	0,8 - 1	0,87 - 1,08	0,7 - 0,9	0,76 - 0,98	NA	NA	NA	NA
JAPAN	277,00	2,37	244,00	2,09	244,00	2,09	221,00	1,89	NA	NA	NA	NA
KOREA	1 500 - 2 000	1,27 - 1,7	2 200 - 2 300	1,87 - 1,95	NA	NA	1 400 - 2 000	1,19 - 1,7	NA	NA	NA	NA
MALAYSIA	5,5 - 6	1,33 - 1,45	4,5 - 5,5	1,09 - 1,33	3,7 - 4,5	0,89 - 1,09	3,5 - 4,4	0,84 - 1,06	7,5 - 8	1,81 - 1,93	25 - 35	6,03 - 8,45
PORTUGAL	1,40	1,52	1,20	1,30	1,00	1,08	0,6 - 0,8	0,65 - 0,87	2,00	2,17	1,60	1,73
SPAIN	1,4 - 1,5	1,52 - 1,63	0,8 - 1,2	0,87 - 1,3	NA	NA	0,88	0,95	2,5 - 3	2,71 - 3,25	NA	NA
SWEDEN	14,80	1,66	12,20	1,37	10,70	1,20	9,30	1,05	25,00	2,81	20,00	2,25
SWITZERLAND	2,2 - 4	2,15 - 3,91	1,1 - 2,5	1,07 - 2,44	0,9 - 1,5	0,88 - 1,46	NA	NA	10 - 15	9,77 - 14,65	8 - 7	7,81 - 6,84
USA	2,88	2,88	1,55	1,55	NA	NA	0,98	0,98	NA	NA	NA	NA

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

SOURCE IEA PVPS.

On average, the price of PV modules in 2017 (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 2017, 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 2017). However, module prices for utility-scale plants have been reported below the average values, down to less than 0,25 USD/Wp at the end of 2017. But the most significant impact on module prices came after May 31 2018, when China decided to constraint its market. The prices of PV modules was seen significantly below 0,25 USD/Wp with lows around 0,21-0,22 USD/Wp. This comes from a new imbalance between production and demand, with dozens of GW of new production capacities added in 2017 and 2018 in all segments of the value chain while the market is now expected to stagnate. Prices below 0,3 USD/Wp can hardly generate benefits and it is generally admitted that companies are not selling a large part of their production at these low levels. 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. One can also assume that the most competitive Thin Film technologies can outperform traditional crystalline silicon 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	0,53 - 1,35	0,4 - 1
AUSTRIA	EUR	0,38 - 0,63	0,4 - 0,7
BELGIUM	EUR	0,35 - 0,5	0,4 - 0,5
CANADA	CAD	0,75 - 0,81	0,6 - 0,6
CHINA	CNY	3	0,4
DENMARK	DKK	2 - 4	0,3 - 0,6
FINLAND	EUR	0,4 - 0,55	0,4 - 0,6
GERMANY	EUR	0,38 - 0,5	0,4 - 0,5
ISRAEL	ILS	1,30	0,3
ITALY	EUR	0,32 - 0,56	0,3 - 0,6
JAPAN	JPY	131	1,12
KOREA	KRW	456 - 646	0,4 - 0,5
MALAYSIA	MYR	1,34 - 1,54	0,3 - 0,4
PORTUGAL	EUR	0,3 - 0,6	0,3 - 0,7
SPAIN	EUR	0,45 - 0,64	0,5 - 0,7
SWEDEN	SEK	4,1 - 6,6	0,5 - 0,7
USA	USD	0,39	0,39

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

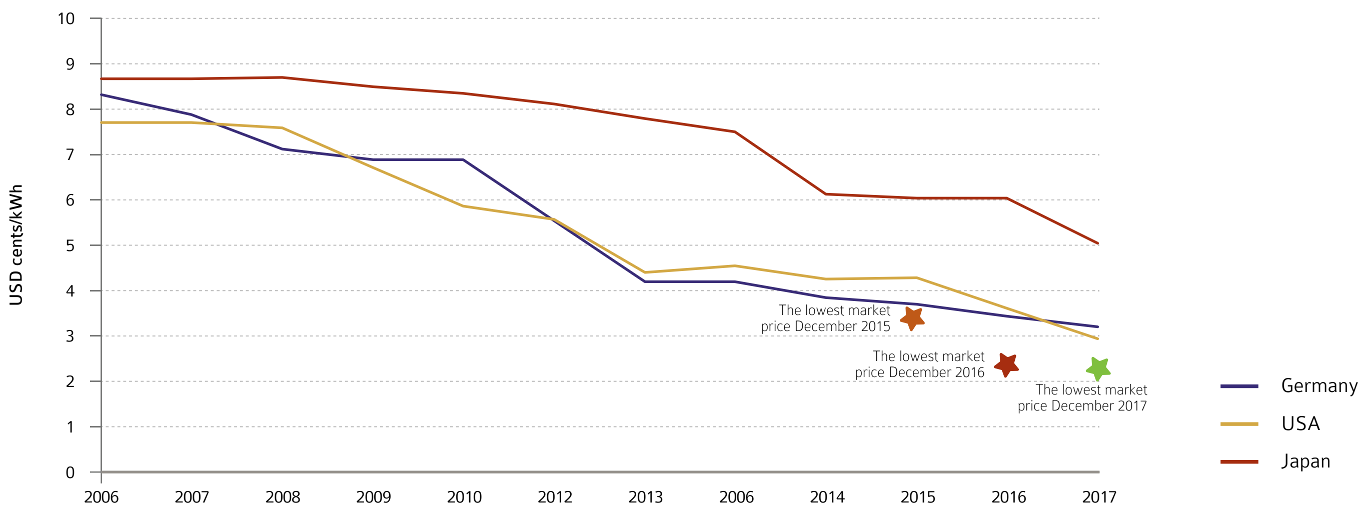
SOURCE IEA PVPS.

The production costs for modules continued to decline as well, with several tier 1 module manufacturers reporting at the end of 2017 production costs around 0,3 USD/Wp and declining, with some possibilities to beat the 0,25 USD/Wp threshold before 2020. First Solar's announcement in 2017 to change its production lines for its new products also aims at reducing its production costs significantly, 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 continuing in 2017. Figure 27 shows the evolution of prices for PV modules 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.

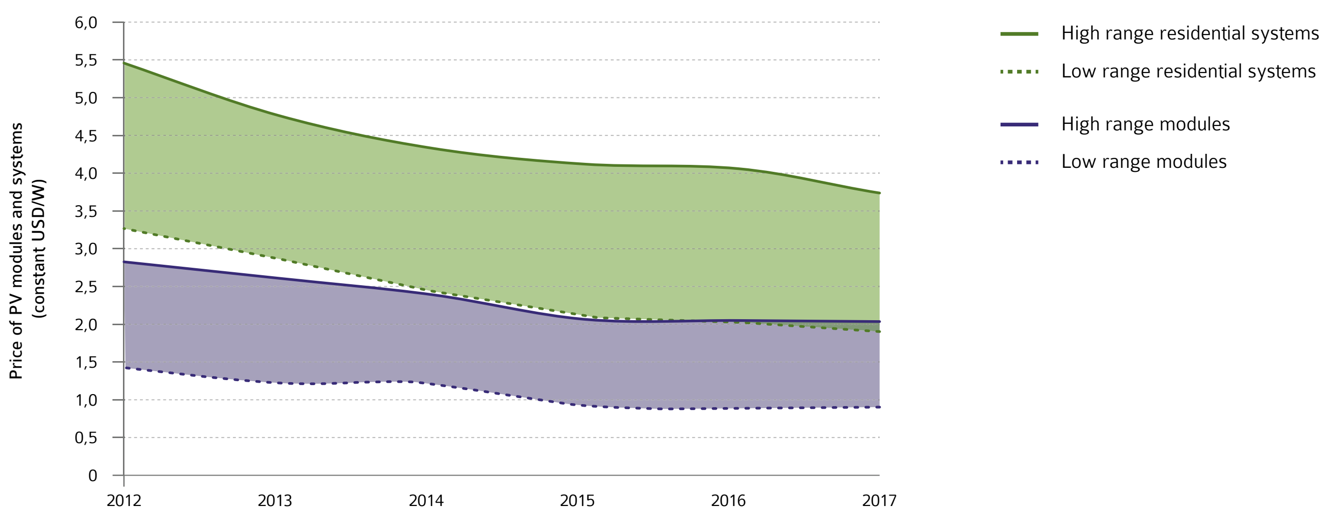
System prices for residential PV systems reveal huge discrepancies from one country to another. In particular the final price of modules as seen above, but also the other price components, such as the inverter, the rest of the BoS and the installation costs. The following figures illustrate such differences 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.

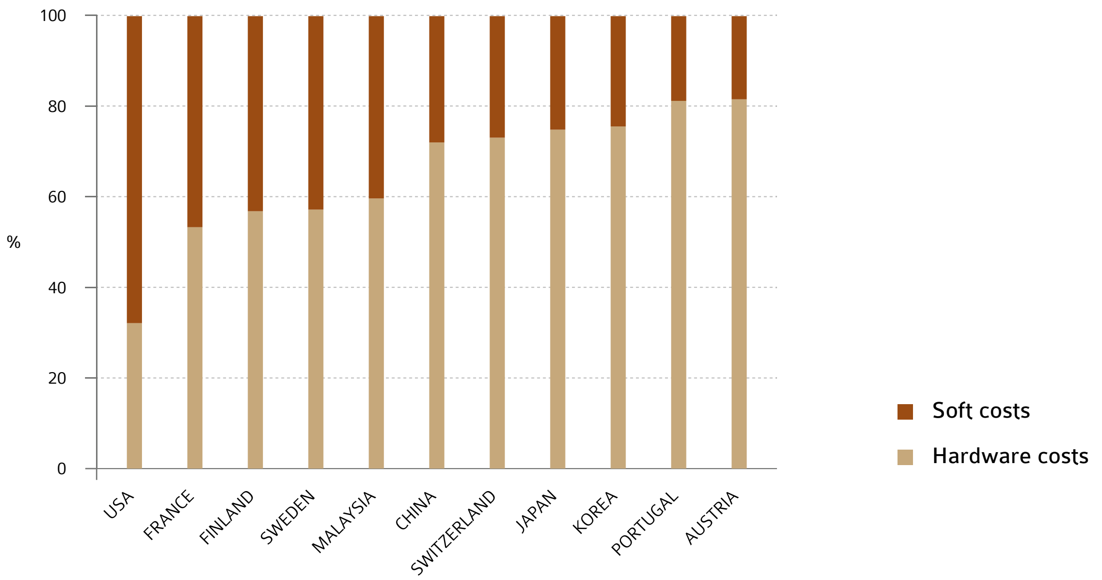
FIGURE 27: EVOLUTION OF PV MODULES AND SMALL-SCALE SYSTEMS PRICES IN SELECTED REPORTING COUNTRIES 2012 - 2017 USD/W



SOURCE IEA PVPS & OTHERS.

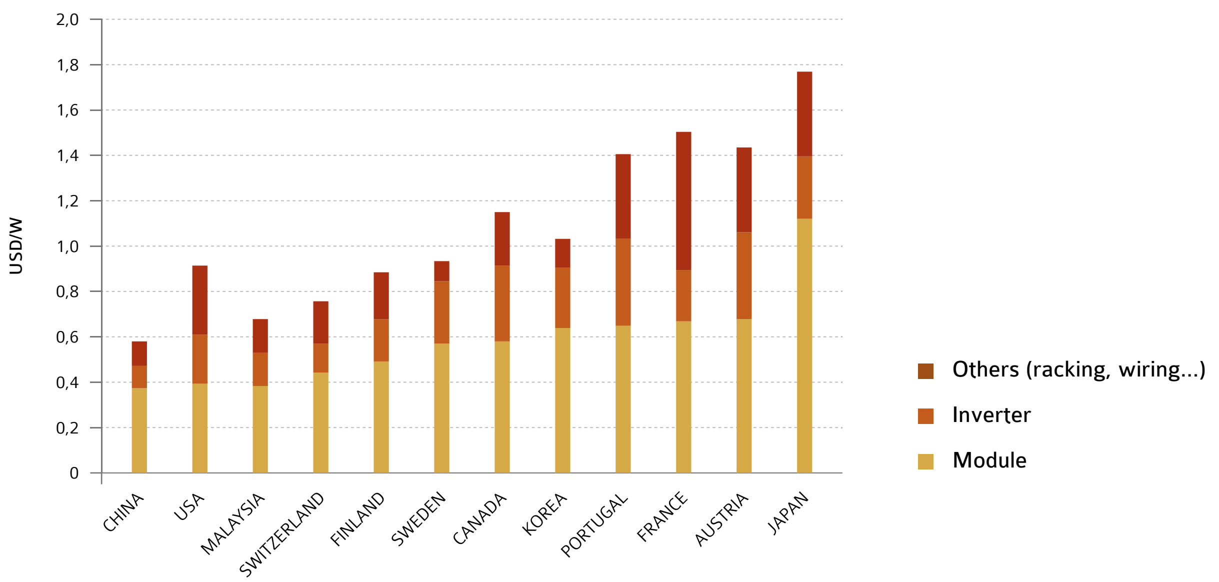
SYSTEM PRICES / CONTINUED

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



SOURCE IEA PVPS.

FIGURE 29: RESIDENTIAL SYSTEM HARDWARE COST BREAKDOWN



SOURCE IEA PVPS.

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.

COST OF PV ELECTRICITY

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 managemnt 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:

- 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; the key challenge is the future evolution.
- 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.

Figure 30 shows how grid parity has already been reached in several countries and how declining electricity costs are paving the way for more countries becoming competitive for PV. The figure shows the range of retail prices in selected countries based on their average solar resource and the indicative PV electricity threshold for 3 different system prices (1, 2 and 3 USD/Wp, converted into LCOE). Green dots are cases where PV is competitive in most of the cases. Orange dots show where it really depends on the system prices and the retail prices of electricity. Red dots are only competitive under very good conditions.

COMPETITIVENESS OF PV ELECTRICITY WITH WHOLESALE ELECTRICITY PRICES

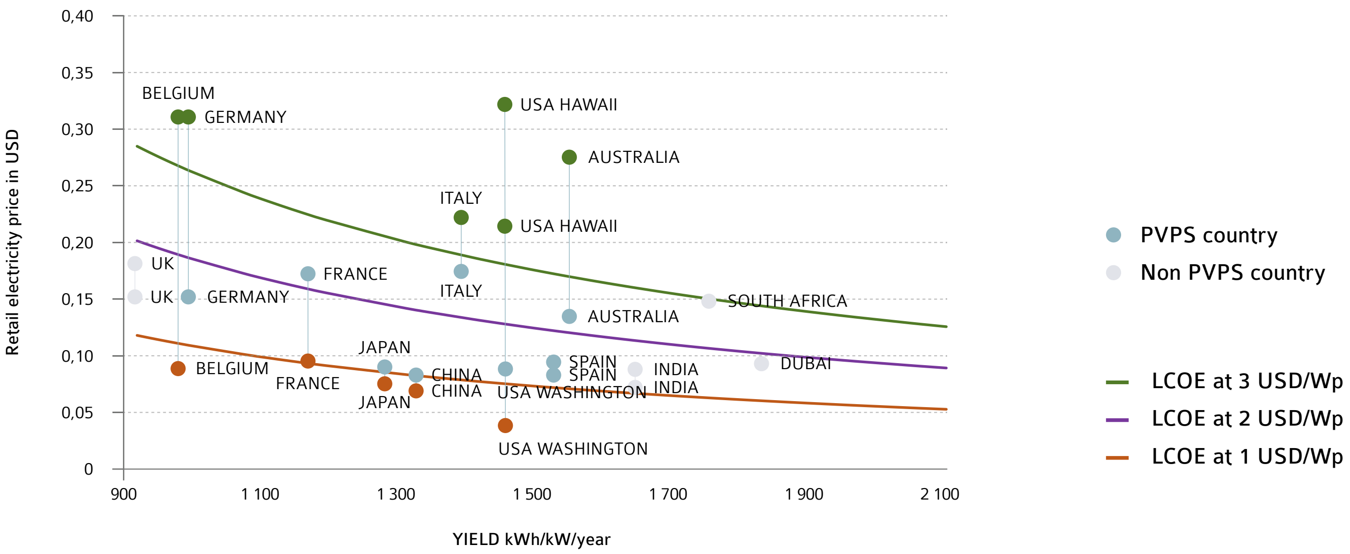
In countries with an electricity market, wholesale electricity prices at the moment when PV produces are one benchmark of PV competitiveness. These prices depend on the market organisation and the technology mix used to generate electricity. In order to be competitive with these prices, PV electricity 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,

COST OF PV ELECTRICITY / CONTINUED

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.

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 2017 AND 2018

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 2017 and in 2018. 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 0,8 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. These projects 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 2017 in the USA but with the help of the tax credit. Even in Europe, 2017 saw PPAs going down to less than 5 USDcents/kWh in Spain and 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. See Table 3 for a view of the most competitive tenders prices.

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 and 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 shown here is an estimate.

As it is evident from the Figure 31, some small countries have taken the lead of the highest PV penetration.The speed at which PV can be deployed has pushed Honduras up to 10% penetration mark and Malta above the 9%.

Italy remains the number one country in the IEA PVPS network with 8,1% of its electricity coming from PV in 2017, slightly higher than 2016. Germany is following with more than 7% corresponding to 42,49 GW installed (producing up to 50% of the instantaneous power demand on some days, and around 14% of the electricity during the peak periods).

Among the others IEA PVPS reporting countries, Belgium remains below the 4,5% mark, followed by Australia (3,8%), Spain (3,6%), Switzerland (around 3%).

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

- Estimated PV installed and commissioned capacity on 31.12.2017.
- 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.

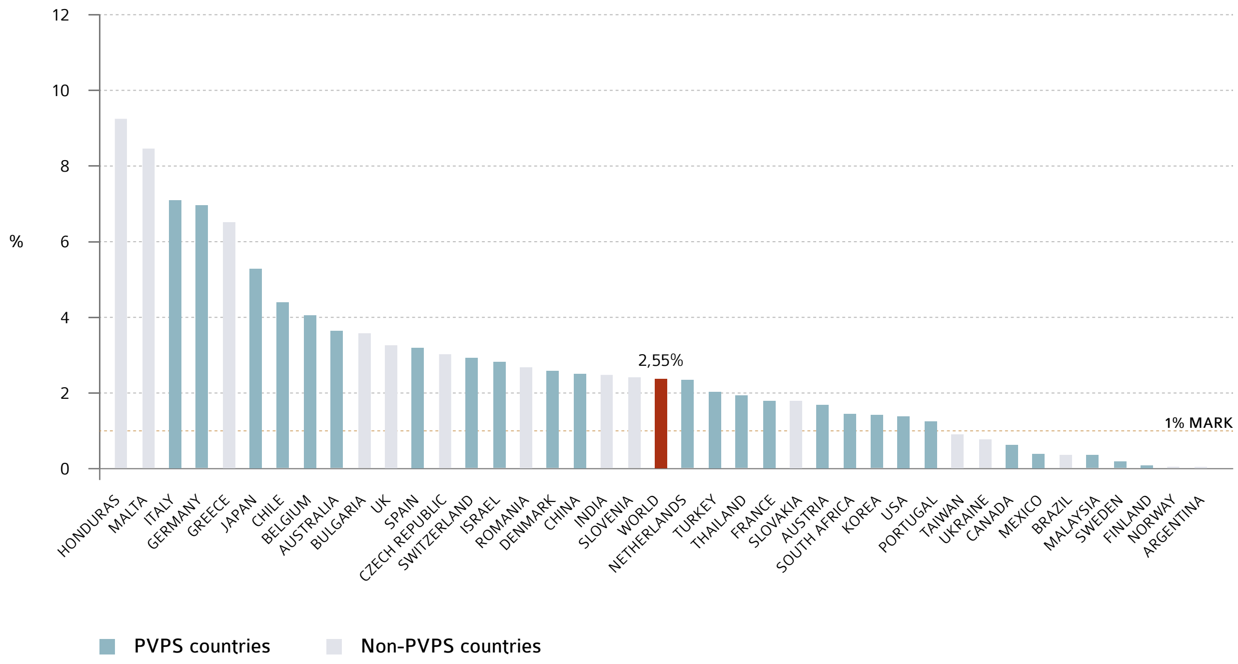
Outside the IEA PVPS network, Greece ranks in the top European countries with 7% PV Penetration calculated on the installed capacity reached in 2017, while Bulgaria almost reached the 4%,followed by U.K (3,5%) and Czech Republic (3,3%). Japan has reached the 5,7% mark, a remarkable level in a country with a modern economy.

Finally, Israel, Denmark and China are below the 3%, followed by Turkey, Thailand, France and Austria. USA, Korea and Portugal are dip below the 2%. Many other countries have lower production numbers, but in total 31 countries produced at least 1% of their electricity demand from PV in 2017.

Figure 31 shows how PV theoretically contributes to the electricity demand in IEA PVPS countries, based on the PV capacity at the end of 2017.

PV ELECTRICITY PRODUCTION / CONTINUED

FIGURE 31: PV CONTRIBUTION TO THE ELECTRICITY DEMAND IN 2017



SOURCE SOURCE IEA PVPS & OTHERS.

GLOBAL PV ELECTRICITY PRODUCTION

With around 403 GW installed worldwide, PV could produce more than 531 TWh (see Table 8) of electricity on a yearly basis. With the world's electricity consumption of almost 21 000 TWh in 2017, this represents 2,5% of the electricity global demand covered by PV (figure 32).

Figures 33 shows the new renewable installed capacity in 2017. With 99 GW out of 178,8 GW, Solar PV was the top source of new power generating capacity in 2017. It was even more than the net additions of fossil fuels and nuclear power combined (Source: REN 21).

In 2017, PV represented 55% of the world's newly installed capacity of renewables, excluding hydropower. Wind power represented 29% with 55 GW installed.

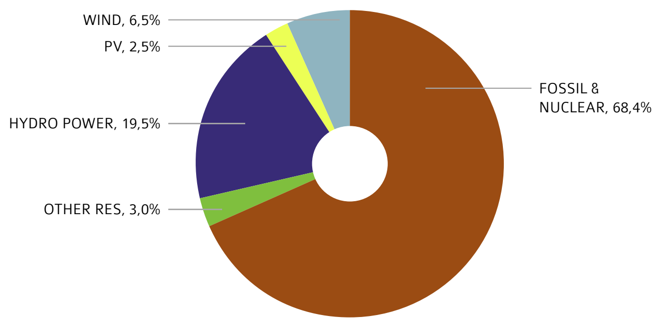
In the last seventeen years, PV installed capacity ranked second in Europe with more than 107 GW installed, after wind (158,3 GW), ahead of gas (96,7 GW) and ahead all other electricity sources, while conventional coal and nuclear were massively decommissioned.

The trend is not so different outside Europe and the speed of transformation increases. In China, PV represented almost 40% of the new capacity installed in the country in 2017: out of 133,72 GW of new power generation capacity installed in 2017, 54 GW were non renewables, 53 GW of PV, followed by wind (15 GW), hydropower (9 GW) and Biomass (3 GW). In 2015, China reached 100% of electrification (NSR China).

In 2017, Japan installed 8,9 GW (AC) of new power generation capacities including 80,8% of renewables and considering hydropower. In the USA, renewables represented 14,6 out of 25,6 GW (AC) of new capacities. In Australia, 1,8 GW of power generation capacity was installed in 2017, out of which 73% were PV systems. In Switzerland renewables represents more than 80% of total power generation capacities (17,6 GW out of 21,4 GW) and pump hydro storage counts for 4,3% of the Hydropower generated capacity, an interesting sign of the growing need to store electricity. Korea installed 6,3 GW of new production capacities including 2,4 GW coming from renewables among which PV counts for 1,37 GW.

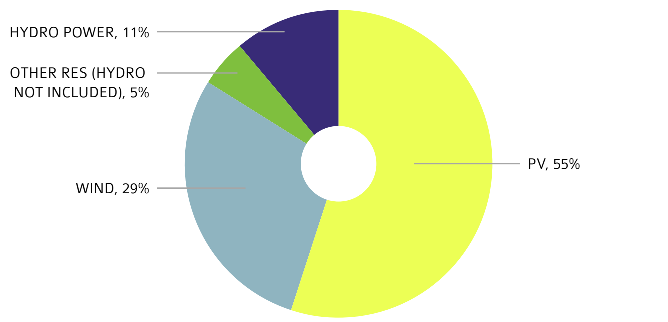
In general, the interest is shifting towards renewables with a growing trend of fossil power plants decommissioning.

FIGURE 32: SHARE OF PV IN THE GLOBAL ELECTRICITY DEMAND IN 2017



SOURCE REN21, IEA PVPS.

FIGURE 33: NEW RENEWABLE INSTALLED CAPACITY IN 2017



SOURCE REN21, IEA PVPS.

TABLE 8: PV ELECTRICITY STATISTICS IN IEA PVPS REPORTING COUNTRIES 2017

COUNTRY	FINAL ELECTRICITY CONSUMPTION 2017 (TWh)	HABITANTS 2017 (MILLION)	GDP 2017 (BILLION USD)	SURFACE (km²)	AVERAGE IRRADIATION kWh/kWp	PV ANNUAL INSTALLED CAPACITY 2017 (MW)	PV CUMULATIVE INSTALLED CAPACITY 2017(MW)	PV ELECTRICITY PRODUCTION (TWh)	ANNUAL CAPACITY PER HABITANT (W/Hab)	CUMULATIVE CAPACITY PER HABITANT (W/Hab)	CUMULATIVE CAPACITY PER KM² (kW/km²)	THEORETICAL PV PENETRATION (%)
AUSTRALIA	259	25	132	7 690 000	1 400	1 309	7 470	10,2	52,4	298,8	1,0	3,9%
AUSTRIA	71	9	42	83 879	1 025	173	1 271	1,295	19,7	144,4	15,1	1,8%
BELGIUM	82	11	49	30 528	925	289	3 877	3,5	25,4	340,1	127,0	4,4%
CANADA	507	37	165	9 985 000	1 150	249	2 974	3,4	6,7	80,4	0,3	0,7%
CHILE	73	18	28	756 096	1 699	892	2 037	3,5	49,6	113,2	2,7	4,7%
CHINA	6 308	1 386	1 224	9 562 911	1 300	53 068	131 140	170,0	38,3	94,6	13,7	2,7%
DENMARK	31	6	32	43 090	950	61	910	0,9	10,1	151,7	21,1	2,8%
FINLAND	86	6	25	338 420	900	43	80	0,1	7,2	13,4	0,2	0,1%
FRANCE	482	67	258	549 087	1 160	875	8 076	9,3	13,1	120,5	14,7	1,9%
GERMANY	541	83	368	357 170	960	1 776	42 492	40,8	21,4	511,9	119,0	7,5%
ISRAEL	56	9	35	22 070	1 750	103	978	1,7	11,4	108,6	44,3	3,0%
ITALY	321	61	193	301 340	1 251	414	19 682	24,6	6,8	323,0	65,4	7,7%
JAPAN	906	127	487	377 962	1 050	7 459	49 500	51,8	58,7	389,8	131,0	5,7%
KOREA	508	51	153	100 266	1 314	1 371	5 873	7,7	26,9	115,1	58,6	1,5%
MALAYSIA	144	32	31	330 800	1 400	60	402	0,5	1,9	12,6	1,2	0,4%
MEXICO	270	129	115	1 964 380	1 708	285	674	1,1	2,2	5,2	0,3	0,4%
NETHERLANDS	115	17	83	41 500	994	853	2 938	2,9	50,2	172,8	70,8	2,5%
NORWAY	134	5	40	385 178	882	17	44	0,0	3,4	8,7	0,1	0,0%
PORTUGAL	48	10	22	92 220	1 160	64	581	0,6	6,4	58,1	6,3	1,3%
SPAIN	268	47	131	505 940	1 745	148	5 331	9,2	3,2	113,4	10,5	3,5%
SWEDEN	141	10	54	447 420	950	118	322	0,3	11,8	32,2	0,7	0,2%
SWITZERLAND	59	8	68	41 285	970	242	1 907	1,8	30,3	238,3	46,2	3,2%
SOUTH AFRICA	193	57	35	1 219 090	1 733	69	1 759	3,0	1,2	30,9	1,4	1,6%
THAILAND	194	69	46	513 120	1 522	251	2 698	4,1	3,6	39,1	5,3	2,1%
TURKEY	228	81	85	783 560	1 471	2 588	3 427	5,0	32,0	42,3	4,4	2,2%
USA	4 015	326	1 939	9 831 510	1 160	10 682	51 638	59,9	32,8	158,4	5,3	1,5%
WORLD	20 863	7 530	8 068	134 325 435	1 327	98 947	403 294	531,6	13,1	53,6	3,0	2,5%

NOTE: THE PV PENETRATION HAS BEEN CALCULATED ACCORDING TO THE GRID CONNECTED PV CUMULATIVE INSTALLED CAPACITY IN 2017.

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 around 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. Energy companies such as E.ON and RWE, listed in the top five leaders affecting the electricity market and production, have recently signed a transaction agreement according to which they are creating two focused European energy companies headquartered in Germany. E.ON planned to acquire RWE's stake in innogy in return and aims at becoming a game changer in the decentralised energy world while RWE will work to become one of the European leaders for renewable energy and security supply. They are developing new innovative solutions for the PV market to target PV on rooftop customers (e.g. Google Sunroof, E.ON SolarCloud, E.ON Aura solar systems) providing PV and storage-based solution for end-consumers.

In France, EDF and ENGIE are the national major energy companies. At the end of 2017 EDF, through its subsidiary EDF EN, has launched the EDF Solar Power Plan that aims at developing and building 30 GWp of Solar PV projects in France over the period 2020 - 2035, in addition to its other activities in France and worldwide. The second subsidiary EDF EN Photowatt, a vertically integrated PV manufacturer, announced a new project based on a new industrial model and on the deployment of its research and development. A new company branded "Photowatt Crystal Advanced" will be specialised in low carbon production of advanced technology silicon ingots and wafers owned by EDF EN, CSI and ECM Greentech. The subsidiary EDF-ENR, as of end of 2017, remotely supervises more than 950 solar plants for a total of around 1 GW. ENGIE (formerly GDF Suez), the French gas and engineering company, has aggressively invested in both RES production and major RES market players in France, such as the CNR and Solair Direct. It is the biggest solar generator in France, with 900 MW in operation, and a comprehensive offer on all market segments, from residential to public and private development of utility scale ground-based systems. Total, the French oil and gas giant, aims at increasing its renewably sourced electricity production capacity to 5 GW within 5 years. Through its three affiliates - Total Solar, SunPower and Total Eren - Total is now developing its position in PV electricity generation capacity, covering the value chain from manufacturing cells to selling solar power. In addition, thanks to its affiliate Saft, these positions in renewable power generation are complemented by investments in storage capacity.

Impacts of pv on climate change

Climate change has developed in the last decade as one of the key challenges for mankind. Science showed that emissions of Greenhouse gases (GHG) and especially CO_2 are the key factor behind man-made climate change. To avoid uncontrollable consequences, the electricity sector is expected to reduce its emissions dramatically, by shifting to new technologies.

PV technology is making a significant contribution to the reduction of greenhouse gases. In terms of CO_2, considering the average emissions of PV (25 g CO_2eq/kWh) are twenty times lower than the global average emissions (491 g/kWh - IEA), the global PV park allows to avoid emissions of more than 247 Mt, which represents approximately the annual emissions of countries such as Spain, Thailand or the Benelux.

It is also equivalent to taking 140 million cars off the road or planting 164 million trees each year.

In Italy, ENEL is the main national utility. In 2017, ENEL Green Power (EGP), the RES-focused subsidiary, counts 2,64 GW of PV installed in Africa, the USA and Europe and It entered Oceania acquiring the largest PV project in Australia (270 MW). It won several competitive tenders in several key countries and appears as one of the leading developers. In addition, EGP has in Italy its own 3SUN "sun-factory" founded as a joint venture with Sharp and STMicroelectronics and now totally owned by EGP. 3SUN combines research and innovation to produce new-generation PV modules (made of thin-film multi-junction composed of amorphous and microcrystalline silicon). Finally, In 2017, it announced its willingness to shift the production towards mainly HeteroJunction cells and modules.

In Switzerland, an increasing numbers of electricity utilities are entering the PV business. Especially larger utilities that have their own (non-solar) electricity production facilities have been under increasing financial pressure, due to falling electricity prices on the European market, and are therefore expanding their business activities. Other small local utilities are taking a positive approach towards the development of PV, as in Sweden by proposing investment in PV plants in exchange of rebates on the electricity bills or free electricity.

In Denmark, Eniig (formerly EnergiMidt) has promoted the use of PV and since 2009 several distribution utilities have included PV technology in their portfolio of products. For a couple of years, the utility made use of capital incentives for customers willing to deploy PV but is now marketing PV without any special support.

In Austria, Wien Energy, 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, Federation of Electric Power Companies (FEPC) groups the ten General Electricity Utilities. The overall trend is that utilities are engaging into the development of PV systems across the country and have started using PV in their own facilities.

In China, National Energy Administration (NEA) issued the PV quota of 2017 - 2020: 86,5 GW including 32 GW of Top Runner Program (8 GW per year) involving most utilities in solar development. Overall, 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, given the diversity in market structures, the interest from electricity utility businesses is equally variable. As an example, In Ontario, several utilities have established unregulated subsidiaries to act as generators and participate in Ontario's Feed-In Tariff programme while others simply interconnect projects and handle the settlement of payments. The utility company of Calgary, ENMAX Corporation (ENMAX) has installed to date over 600 systems representing approximately 50% of the installed solar in Alberta.

Calgary Utility developed its Generate Choice Programme where it offers customers a selection of pricing programmes for 1,3 kW systems or more. Roof leasing exists in parallel to the offering of turnkey solutions. Utility involvement offers 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. Financially, PV is reducing the amount of energy transported and sold, and reducing the wholesale electricity price during the daytime. Technical issues most commonly relate to impacts upon local voltages, and network operators have been given the ability to constrain the amount of PV that is connected to their networks, and impose these constraints upon individual applicants unless applicants used inverters with operation modes under the network operators' influence. 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 – THE MILESTONE

2017 was a year that saw the PV market growing close to 100 GW. Such a market level was considered impossible by many a few years ago, when PV systems used to hardly reach a few GW of yearly installations.

The year 2017 experienced again a significant growth 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: Three of the top four markets from 2017 were located in Asia (China, India and Japan), followed by a declining US market and a stable European one. While China has installed more than half of all new installations, the growth of the rest of the PV market was significant enough to conclude that this was the entire PV market that was growing, including emerging countries.

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, confirming the globalization trends.

In Asia, next to China, India and Japan, Thailand, Korea, Taiwan, Vietnam, Malaysia, the Philippines and many other countries are starting or continuing to develop. The Americas are following at an accelerated pace, with Latin America starting to engage in PV development in Brazil, Chile, Mexico, Peru, Panama, Honduras and more.

In Africa, South Africa and Morocco are followed by Algeria, and rapidly Egypt will contribute significantly. In the Middle-East, the tenders have accelerated the development and more should come in the coming years from Saudi Arabia, the UAE and more. In the meantime, Turkey became a GW market and Israel reached close to 1 GW.

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 production cost. This is also true in several other countries for utility-scale PV or hybrid systems. The distributed segments that experienced difficulties in many countries, due to the difficulties to set-up sometimes complex regulations for self-consumption, increased significantly in 2017, thanks mainly, but not only, to China. In several European countries, collective and virtual self-consumption schemes have been implemented and will start to deliver in 2018.

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, including wind in some locations.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 political subject that will have to be scrutinized.

The road to PV competitiveness is open but remains complex and linked to political decisions. The Chinese decision to control its market development, announced in May 2018, is shaking the entire PV industry and reshaping the market landscape. This decision impacts temporary module prices (which are going down very fast), questions short-term investments in the industry and impacts industry development plans.

Nevertheless, the assets of PV are numerous and as seen in this 23rd 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 PV has the ability to continue progressing fast and become the major source of electricity in the world, offering a solution for decarbonizing the electricity mix.

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 2017

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	2017
IEA PVPS COUNTRIES																										
AUSTRALIA	7	9	11	13	16	18	21	23	26	30	35	41	47	55	64	74	104	199	591	1473	2572	3411	4274	5294	6161	7470
AUSTRIA	0	0	0	0	0	0	0	0	0	0	0	0	21	24	26	29	32	54	97	189	265	628	787	939	1098	1271
BELGIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	110	667	1096	2164	2890	3154	3266	3386	3587	3877
CANADA	1	1	2	2	3	3	4	6	7	9	10	12	14	17	20	26	33	95	281	558	827	1272	1904	2579	2725	2974
CHILE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	12	223	590	1145	2037
CHINA	0	0	0	0	0	0	0	0	11	16	34	44	54	62	72	92	132	292	792	3492	7052	17732	28372	43522	78072	131140
DENMARK	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3	5	7	17	408	563	606	779	849	910
FINLAND	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	3	5	7	8	8	8	8	20	37	80
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	7201	8076
GERMANY	3	4	6	7	10	16	22	30	89	207	324	435	1105	2056	2899	4170	6120	10566	18006	25916	34077	36710	37900	39224	40716	42492
ISRAEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	22	67	186	272	377	587	771	875	978
ITALY	8	12	14	16	16	17	18	18	19	20	22	26	31	37	50	100	496	1277	3605	13141	16796	18197	18606	18915	19283	19682
JAPAN	19	24	31	43	60	91	133	209	330	453	637	860	1132	1422	1708	1919	2144	2627	3618	4914	6632	13599	23339	34150	42040	49500
KOREA	0	0	0	0	0	0	0	0	0	0	5	6	9	14	36	81	357	524	650	729	1024	1555	2481	3615	4502	5873
MALAYSIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	3	32	139	204	264	342	402
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	674
MOROCCO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	15
NETHERLANDS	0	0	0	0	1	1	1	5	9	16	22	40	43	45	48	49	53	64	85	143	363	723	1123	1560	2085	2938
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	44
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	581
SOUTH AFRICA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	228	1008	1100	1690	1759
SPAIN	0	0	1	1	1	1	1	2	2	2	4	4	12	28	138	701	3690	3739	4224	4687	5017	5103	5126	5164	5182	5331
SWEDEN	1	1	1	2	2	2	2	3	3	3	3	4	4	4	5	6	8	9	11	15	23	42	78	126	205	322
SWITZERLAND	5	6	7	7	8	10	11	13	15	18	19	21	23	27	30	36	48	74	111	211	437	756	1061	1394	1664	1907
THAILAND	0	0	0	0	0	0	0	0	0	0	0	0	0	24	30	32	33	43	49	242	388	825	1299	1421	2447	2698
TURKEY	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	6	12	48	256	839	3427
USA	0	0	0	0	0	0	0	0	0	0	0	0	111	190	295	455	753	1188	2017	3937	7130	12076	18321	25821	40956	51638
TOTAL IEA PVPS	46	60	84	103	131	177	234	338	543	808	1156	1540	2659	4063	5495	7920	14394	21965	36701	65231	90631	122297	156935	198227	264636	348066
TOTAL NON IEA PVPS	0	0	0	0	0	0	0	0	1	2	3	17	29	34	38	49	135	754	2888	5477	9990	15427	19954	29682	39711	55228
TOTAL	46	60	84	103	131	177	234	338	544	810	1160	1557	2688	4096	5533	7968	14529	22719	39589	70708	100621	137724	176889	227909	304347	403294

SOURCE SOURCE IEA PVPS & OTHERS.

ANNEX 2: ANNUAL INSTALLED PV CAPACITY (MW) FROM 1992 TO 2017

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	2017
IEA PVPS COUNTRIES																										
AUSTRALIA	7	2	2	2	3	3	3	2	3	4	5	6	6	8	9	11	30	95	392	883	1098	839	863	1020	867	1309
AUSTRIA	0	0	0	0	0	0	0	0	0	0	0	0	21	3	2	3	4	22	43	92	76	363	159	152	159	173
BELGIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	86	557	429	1068	726	264	112	120	201	289
CANADA	1	0	0	0	1	1	1	1	1	2	1	2	2	3	4	5	7	62	187	277	269	445	633	675	146	249
CHILE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	9	210	367	555	892
CHINA	0	0	0	0	0	0	0	0	11	5	19	10	10	8	10	20	40	160	500	2700	3560	10680	10640	15150	34550	53068
DENMARK	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	3	10	391	156	42	173	70	61
FINLAND	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	2	2	0	0	0	12	17	43
FRANCE	2	0	0	1	2	2	2	2	2	3	3	4	3	2	12	38	104	191	838	1764	1120	654	954	903	596	875
GERMANY	3	1	1	1	4	6	5	8	59	117	117	111	670	951	843	1271	1950	4446	7440	7910	8160	2633	1190	1324	1492	1776
ISRAEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	21	45	119	86	105	210	184	104	103
ITALY	8	4	2	2	0	1	1	1	1	1	2	4	5	7	13	50	396	781	2328	9536	3655	1402	409	308	368	400
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	7459
KOREA	0	0	0	0	0	0	0	0	0	0	5	1	3	5	22	45	276	167	127	79	295	531	926	1134	887	1371
MALAYSIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	29	107	65	60	78	60
MEXICO	0	0	9	0	1	1	1	1	1	1	1	1	1	1	1	1	1	3	6	9	12	60	67	67	143	285
MOROCCO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	5
NETHERLANDS	0	0	0	0	0	0	0	4	3	8	6	18	4	2	2	1	4	11	21	58	220	360	400	437	525	853
NORWAY	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	11	17
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	64
SOUTH AFRICA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	221	781	92	590	69
SPAIN	0	0	1	0	0	0	0	1	0	0	2	0	8	15	110	563	2989	49	486	463	330	86	23	39	18	148
SWEDEN	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	1	2	4	8	19	35	48	79	118
SWITZERLAND	5	1	1	1	1	1	2	2	2	2	2	2	2	4	3	7	12	26	37	100	226	319	305	333	270	242
THAILAND	0	0	0	0	0	0	0	0	0	0	0	0	0	24	7	2	1	10	6	193	145	437	475	121	1027	251
TURKEY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	6	35	208	583	2588
USA	0	0	0	0	0	0	0	0	0	0	0	0	111	79	105	160	298	435	829	1920	3193	4946	6245	7500	15135	10682
TOTAL IEA PVPS	46	14	24	19	28	47	57	103	206	265	348	384	1118	1404	1432	2425	6474	7571	14736	28529	25401	31665	34639	41292	66409	83430
TOTAL NON IEA PVPS	0	0	0	0	0	0	0	0	1	1	1	13	13	4	5	10	86	620	2133	2590	4512	5438	4526	9728	10029	15517
TOTAL	46	14	24	19	28	47	57	103	207	266	349	397	1131	1409	1437	2435	6560	8191	16870	31119	29913	37103	39165	51020	76439	98947

SOURCE SOURCE IEA PVPS & OTHERS.

ANNEX 3: REPORTED PRODUCTION OF PV MATERIALS, CELLS AND MODULES IN 2017 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											
AUSTRIA											
BELGIUM									17,4		46
CANADA											
CHINA	242 400				79 084		29 790	86 798	53 798	1 000	70 875
DENMARK	0		0		0		NA	NA	NA	NA	NA
FINLAND	0		0		0				6		20
FRANCE	NA		NA		NA			70		NA	500
GERMANY											
ITALY									63		885,4
JAPAN	NA	NA			NA	NA	2 716	2 490	2716	1 074	4 010
KOREA		82 000				2 000		6 505			8 690
MALAYSIA		10		1 000		1 000		5 966	4 683	2 071	6 754
NORWAY											
SPAIN											
SWEDEN	0		0		0		0	3		0	3
SWITZERLAND	0		0		0		0	0	12		355
THAILAND											
USA	29 777		NA		0		263	906	679	291	1 952

NOTES:
1 SOME REPORTED FIGURES ABOVE ARE NOT THE SAME AS DESCRIBED IN CHAPTER 4 DUE TO THE REPORTED TIMING AND SOURCES.

SOURCE IEA PVPS, RTS CORPORATION.

ANNEX 4: AVERAGE 2017 EXCHANGE RATES

COUNTRY	CURRENCY CODE	EXCHANGE RATE (1 USD =)
AUSTRALIA	AUD	1,358
AUSTRIA, BELGIUM, FINLAND, FRANCE, GERMANY, ITALY, THE NETHERLANDS, PORTUGAL, SPAIN	EUR	0,923
CANADA	CAD	1,35
CHINA	CNY	7,03
DENMARK	DKK	6,86
ISRAEL	ILS	3,75
JAPAN	JPY	116,67
KOREA	KRW	1178,59
MALAYSIA	MYR	4,14
MEXICO	MXN	19,68
NORWAY	NOK	8,61
SWEDEN	SEK	8,89
SWITZERLAND	CHF	1,02
THAILAND	THB	35,37
TURKEY	TRY	3,79
UNITED STATES	USD	1,00

SOURCE IRS.

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, Morocco, 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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