Technology Collaboration Programme
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International Energy Agency
Photovoltaic Power Systems Programme

Task 1 Strategic PV Analysis and Outreach

PVPS

TRENDS IN PHOTOVOLTAIC APPLICATIONS 2019

REPORT IEA PVPS T1-36 : 2019

PHOTOVOLTAIC POWER SYSTEMS TECHNOLOGY COLLABORATION PROGRAMME

WHAT IS IEA PVPS TCP?

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of thousands of experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCP's 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 deals with market and industry analysis, strategic research and facilitates the exchange and dissemination of information arising from the overall IEA PVPS Programme.

The IEA PVPS 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, Solar Power Europe, the Smart Electric Power Alliance (SEPA), the Solar Energy Industries Association and the Copper Alliance are also members.

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COVER IMAGE

Ground mounted PV installation in Sayaton, Spain. Copyright G. Neubourg.

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REPORT SCOPE AND OBJECTIVES

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

This report is prepared to assist those who are responsible for developing the strategies of businesses and public authorities, and to support the development of medium-term plans for electricity utilities and other providers of energy services. It also provides guidance to government officials responsible for setting energy policy and preparing national energy plans. The scope of the report is limited to PV applications with a rated power of 40 W or more. National data supplied are as accurate as possible at the time of publication. Data accuracy on production levels and system prices varies, depending on the willingness of the relevant national PV industry to provide data.

This report presents the results of the 24th international survey. It provides an overview of PV power systems applications, markets and production in the reporting countries and elsewhere at the end of 2018 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. 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.

ACKNOWLEDGEMENT

This report has been prepared under the supervision by Task 1 participants. A special thanks to all of them. The report authors also gratefully acknowledge special support of Mary Brunisholz, IEA PVPS and NET Ltd.

FOREWORD

On behalf of the IEA PVPS Technology Collaboration Programme, I am pleased to present the 24th international survey report on Trends in Photovoltaic (PV) Applications to you.

This report, based on careful analysis of the growing and diversifying market for photovoltaic power systems, has been prepared by the IEA PVPS Task 1 expert group "Strategic PV Analysis and Outreach". With a particular focus on IEA PVPS members, the report aims to provide a detailed picture of the worldwide and country-specific photovoltaic market trends, the various drivers and policies, the status of the industry and discusses the increasing role of PV in the energy system. This year's report covers the market and industry development up to 2018 and highlights some more recently observed trends.

Similar to the year before, 103 GW of PV power systems have been installed globally in 2018, bringing the total installed capacity to over 512 GW or half a TW. We observe a confirmation of the strong role of PV deployment in Asia. Despite an important reduction in China's PV market (from 52,9 GW in 2017 to 44,3 GW in 2018), due to changing framework conditions during 2018, this country kept its leadership, both in annual as well as total installed capacity. China's annual installed PV capacity is followed by India (10,8 GW), the United States (10,7 GW), Japan (6,7 GW) and Australia (3,8 GW). Eleven countries installed more than 1 GW in 2018 and 31 countries reached a cumulative capacity of 1 GW and more. The countries with the ten largest annually installed PV capacities account for about 87% of the total annual installed capacity of 103 GW. Regardless of this strong concentration, the number of countries that are entering the PV market with significant market developments is increasing.

On the cost side, further record PPAs have been announced for large scale PV systems at below 2 USDcents per kWh, confirming the increasing competitiveness that PV can reach under the best conditions. Despite these very competitive prices in a favourable market environment, the regulatory framework and its further evolution towards market mechanisms remain significantly important for the further development of worldwide PV markets.

In recent years, utility-scale PV systems have dominated the PV market; however, distributed PV systems, namely on commercial and industrial premises, are becoming more important in many countries, due to their favourable economics; in particular when combined with increased self-consumption. The ongoing cost reduction of PV systems also favours increasing off-grid markets whereby – due to their very small size – these are better characterized by their large number (millions) of installed systems than their installed capacity. Their role in massively bringing affordable electricity services to rural areas in emerging and developing countries is another important trend observed in the PV market. Finally, 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, application and market environments becomes crucial. These are just a few highlights of the wealth of information that this 24th edition of the IEA PVPS Trends report hopes to provide to you!

Stefan Nowak
Chairman
IEA PVPS Programme

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TOTAL BUSINESS VALUE IN PV SECTOR IN 2018

$132 BILLION

TOP 5 PV MARKETS IN 2018

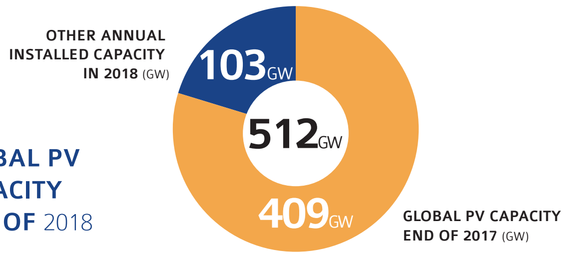
CHINA	44,3 GW
INDIA	10,8 GW
USA	10,7 GW
JAPAN	6,7 GW
AUSTRALIA	3,8 GW

PV CONTRIBUTION TO ELECTRICITY DEMAND

2,9 %

Share of PV in the global electricitiy demand in 2018

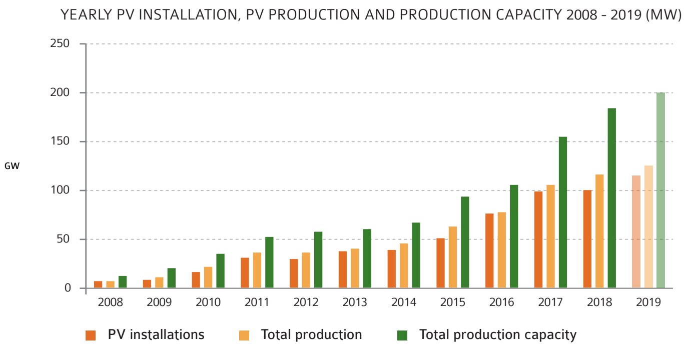
GLOBAL PV CAPACITY END OF 2018



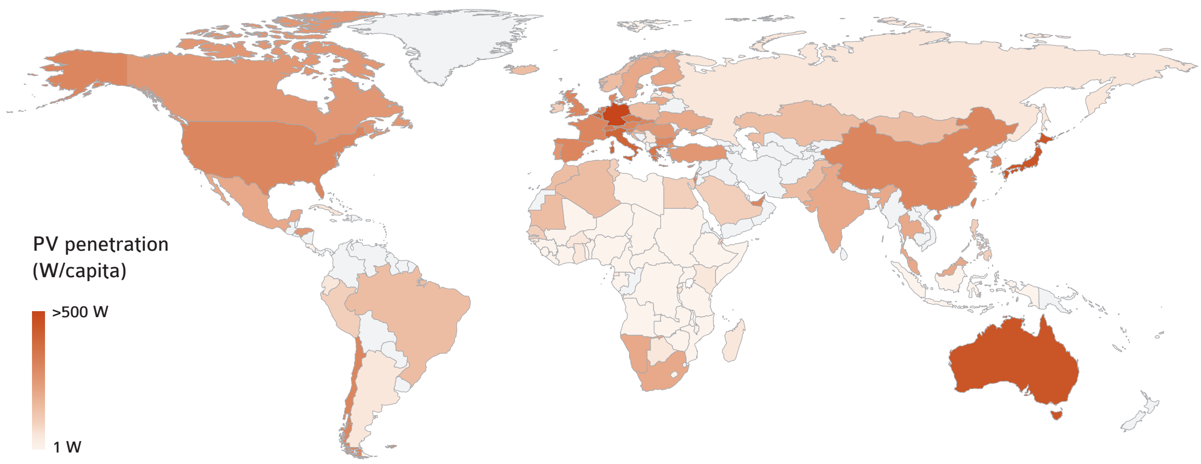
CLIMATE CHANGE IMPACTS

590

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



PV PENETRATION PER CAPITA IN 2018



31 COUNTRIES REACHED AT LEAST **1 GWp** IN 2018

PV POWER PER CAPITA

1. GERMANY (548 Wp)
2. JAPAN (444 Wp)
3. AUSTRALIA (438 Wp)

11 COUNTRIES INSTALLED AT LEAST **1 GWp** IN 2018

SOURCE IEA PVPS AND OTHERS

one

INTRODUCTION TO THE CONCEPTS AND METHODOLOGY

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 156 mm to 166 mm square sizes. 156.75 mm squares is the standard, but wafer sizes, and thus cell sizes are progressively increased, as it is commonly considered by industrial actors as an easy way to improve cell and modules wattage without the necessity to adapt production lines. 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, also called monocrystalline, are formed with the wafers manufactured using a single crystal growth method and have commercial efficiencies between 20% and 24% (single-junction). Multicrystalline silicon (mc-Si) cells, also called polycrystalline, 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 18%-20% in mass production (single-junction).

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. III-V compound semiconductor PV cells are formed using materials such as Gallium Arsenide (GaAs) on Germanium (Ge) substrates and have high conversion efficiencies from 25% up to 30% (not concentrated). Due to their high cost, they are typically used in concentrated PV (CPV) systems with tracking systems or for space applications. 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 thanks to the reduced number of manufacturing steps from raw materials to modules, and to reduced energy demand. Thin-film materials commercially used are cadmium telluride (CdTe), and copper-indium-(gallium)-diselenide (CIGS and CIS). Amorphous (a-Si) and micromorph silicon (μ-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.

Organic thin-film PV (OPV) cells use dye or organic semiconductors as the light-harvesting active layer. This technology has created increasing interest and research over the last few years and is currently the fastest-advancing solar technology. Despite the low production costs, stable products are

PV TECHNOLOGY / CONTINUED

not yet available for the market, nevertheless development and demonstration activities are underway. Tandem cells based on perovskites are researched as well, with either a crystalline silicon base or a thin film base, and could hit the market sooner than pure perovskites products. In 2019, perovskite solar cell achieved 28.0% efficiencies in silicon-based tandem and 23.26% efficiencies in CIGS-based tandems.

Photovoltaic modules are typically rated between 145 W and 450 W, depending of the technology and the size. Specialized products for building integrated PV systems (BIPV) exist, with higher nominal power due to their larger sizes. Crystalline silicon modules consist of individual PV cells connected together and encapsulated between a transparent front, usually glass, and a backing material, usually plastic or glass. Thin-film modules encapsulate PV cells formed into a single substrate, in a flexible or fixed module, with transparent plastic or glass as the front material. Their efficiency ranges between 9% (OPV), 10% (a-Si), 17% (CIGS and CIS), 19% (CdTe), 25% GaAs (non-concentrated) and above 40% for some CPV modules.[1]

A PV system consists of 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 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 10-20% for single axis trackers and 20-30% for double axis trackers compared with fixed systems.

PV APPLICATIONS AND MARKET SEGMENTS

When considering distributed PV systems, it is necessary to distinguish BAPV (building applied photovoltaics) and BIPV (buildings integrated photovoltaics) systems. BAPV refers to PV systems installed on an existing building while BIPV imposes to replace conventional building materials by some which include PV cells. Amongst BIPV solutions, PV tiles, or PV shingles, are typically small, rectangular solar panels that can be installed alongside conventional tiles or slates using a traditional racking system used for this type of building product. BIPV products can take various shapes, colours and be manufactured using various materials, although a vast majority use glass on both sides. They can be assembled in way that they fill multiple functions usually devoted to conventional building envelope solutions.

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% with structure, and possibly up to 25% with a single-axis system, if parameters are optimized. However, with few installations at the end of 2018, bifaciality remains a niche with high potential, though untapped.

PV thermal hybrid solar installations (PVT) combine a solar module with a solar thermal collector, thereby converting sunlight into electricity and capturing the remaining waste heat from the PV module to produce hot water or feed the central heating system. It also allows to reduce the operating of the modules, which benefits the performances of the system.

Floating PV systems are mounted on a structure that floats on a water surface and can be associated with existing grid connections for instance in the case of dam vicinity.

Agricultural PV combine crops and energy production on the same site. The sharing of light between these two types of production potentially allows a higher crop yield, depending on the climate and the selection of the crop variety and can even be mutually beneficial in some cases, as the water which evaporates from the crops can contribute to a reduction of PV modules operating temperature.

Various 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.

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.

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.

1 Source: https://www.nrel.gov/pv/module-efficiency.html

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

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.

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. "Micro-inverters" also exist, which can often be connected to up to 4 modules.

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

Grid-connected distributed PV systems are installed to provide power to a grid-connected customer or directly to the electricity network (specifically where that part of the electricity distribution network is configured to supply power to a number of customers rather than to provide a bulk transport function). Such systems may be on, or integrated into, the customer's premises often on the demand side of the electricity meter, on residential, commercial or industrial buildings, or simply in the built environment on motorway sound-barriers, etc. Size is not a determining feature – while a 1 MW PV system on a rooftop may be large by PV standards, this is not the case for other forms of distributed generation.

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.

METHODOLOGY FOR THE MAIN PV MARKET DEVELOPMENT INDICATORS

This report counts all PV 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.

For this report, the PV penetration was estimated with the most recent global data about the PV installed capacity, the average theoretical PV production and the electricity demand based. In general, PV penetration is amongst one of the best indicators to reflect the market dynamics in a specific country or region. If, a global PV penetration level doesn't reflect the regional disparities, it gives an indication about the ability of the technology to keep up with the global demand growth. Hence, regarding climate goals for instance, the PV penetration is a better indicator than the absolute market growth.

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PV MARKET DEVELOPMENT TRENDS

More than twenty years of PV market development have resulted in the deployment of over 512,3 GW of PV systems throughout the world. Of which over 54% has been installed over the last 3 years. Significant and sometimes abrupt changes have occurred in the dynamics of the major PV markets over the years. Therefore, an in-depth look at the diversity of the major PV markets is needed in order to better understand the drivers of this growth.

PV installation data

A large majority of PV installations include an inverter which converts the variable direct current (DC) output of solar panels into alternating current (AC) to be injected into the electrical grid. PV installation data is reported in DC in this report (see also Chapter 1).

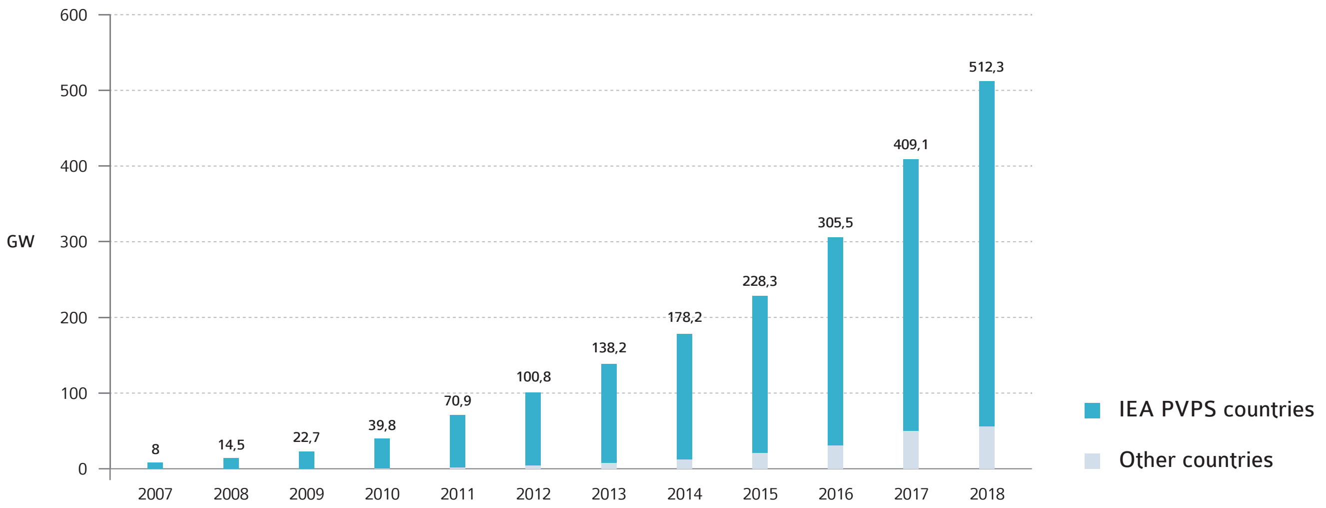
THE GLOBAL PV INSTALLED CAPACITY

The global PV installed capacity represented 512,3 GW of cumulative PV installations altogether, mostly grid-connected, at the end of 2018. The IEA PVPS countries represented 432,7 GW. The other key markets that have been considered and are not part of the IEA PVPS Programme, represented 79,6 additional GW.

With 32,9 GW, India represents almost half of these 79,6 GW, the rest is mainly located in Europe and generally related to historical installations: UK with almost 13,0 GW, Greece with 2,7 GW, the Czech Republic with 2,2 GW installed, Romania with 1,4 GW, Ukraine with 1,3 GW, Bulgaria just above the 1 GW mark and Slovakia with a little bit more than 0,5 GW. The other major countries that accounted for the highest cumulative installations at the end of 2018 and that are not part of the IEA PVPS programme are: Pakistan with an estimated 2,1 GW, Taiwan with 2,7 GW as well, Brazil with 2,3 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 outside the ones mentioned above.

Presently it appears that 103,2 GW represents the minimum capacity installed during 2018 with a firm level of certainty.

FIGURE 2.1: EVOLUTION OF CUMULATIVE PV INSTALLATIONS (GW)



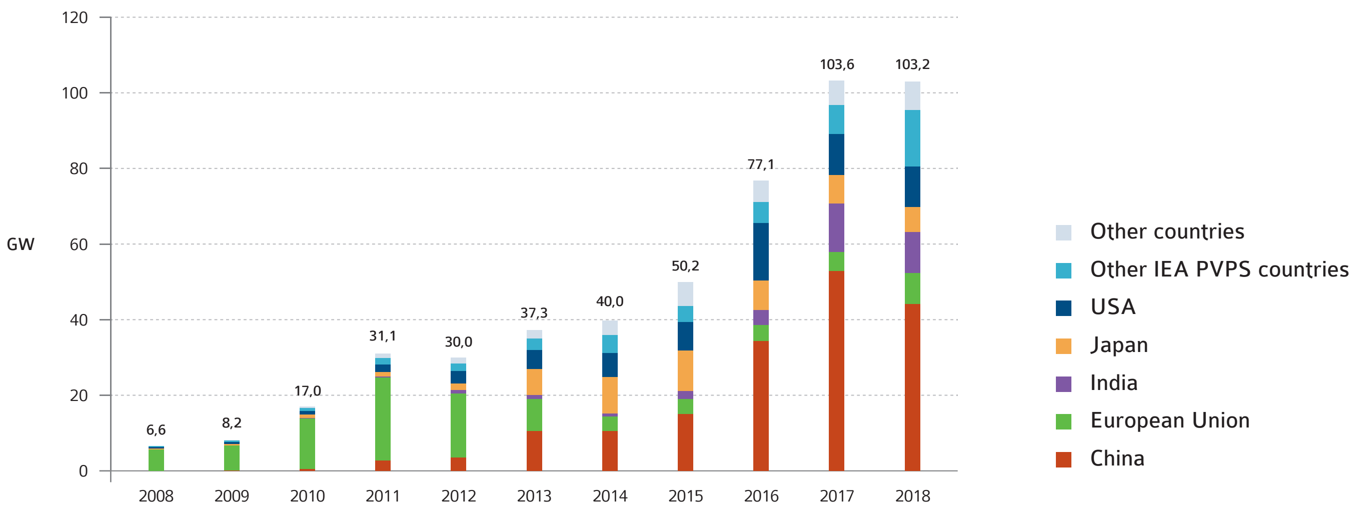
SOURCE IEA PVPS & OTHERS.

THE MARKET EVOLUTION

The 28 IEA PVPS countries installed at least 83,6 GW in 2018. While they are more difficult to track with a high level of certainty, installations in non-IEA PVPS countries contributed an amount of 19,6 GW. The remarkable trend of 2018 is the growth of the global PV market despite the market slow-down in China. The rise of emerging markets contributed to this market stabilization in 2018.

For the sixth year in a row, China is in first place and installed more than 44,3 GW in 2018, according to the Chinese national energy administration; an installation level that is significantly lower than the 52,9 GW newly installed capacity in the country in 2017. Indeed, the country's decision to contain the PV development with short notice impacted the installation rate during the last months of the year and created market uncertainty. The total installed capacity in China reached 175,4 GW, therefore the country keeps its market leader position.

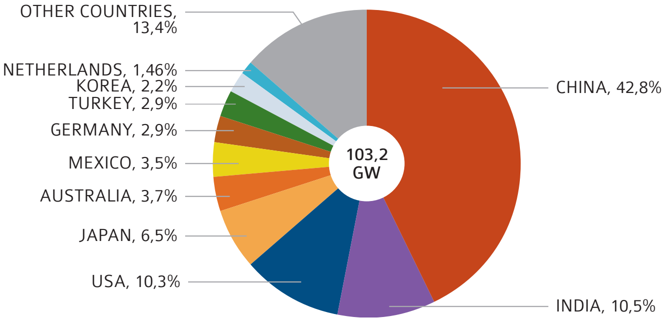
FIGURE 2.2: EVOLUTION OF ANNUAL PV INSTALLATIONS (GW)



SOURCE IEA PVPS & OTHERS.

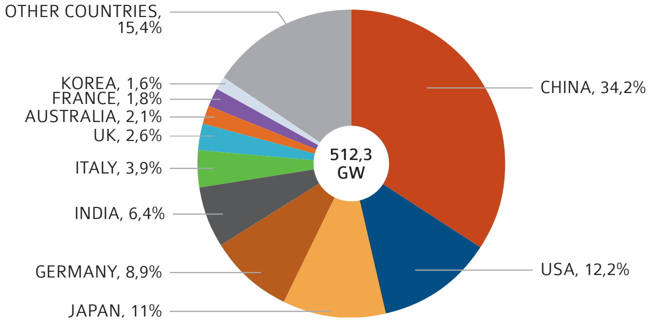
THE MARKET EVOLUTION / CONTINUED

FIGURE 2.3: GLOBAL PV MARKET IN 2018



SOURCE IEA PVPS & OTHERS.

FIGURE 2.4: CUMULATIVE PV CAPACITY END 2018



SOURCE IEA PVPS & OTHERS.

Second is **India** with 10,8 GW installed, a significant growth compared to 2017, with mostly utility-scale plants installed. This number has been recalculated based on official AC data using IEA PVPS assumptions on AC-DC ratio and shows the development of PV installations in the second most populated country.

The **USA** is in third place this year with 10,7 GW installed, out of which 6,2 GW were installed as utility-scale plants.

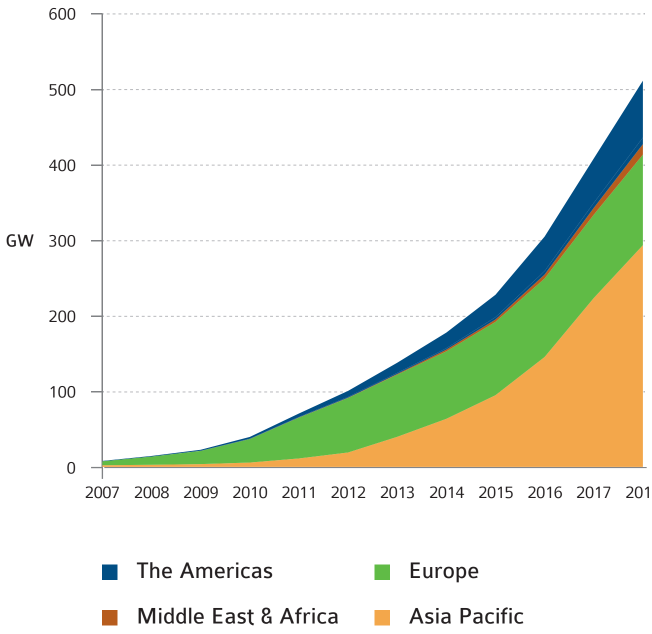
Fourth is the **European Union** which experienced growth for the first time in years with 8,4 GW but still far from the 23,2 GW recorded in 2011. **Germany** and the **Netherlands** were the key markets this year, followed by **France** and several others. With many renewable energy policies regulated at the EU level, renewable energy development can be considered as partially driven by the European institutions and the targets decided at this level.

The market in **Japan** slightly decreased to 6,7 GW installed in the country in 2018. Since the record level of 10,8 GW in 2015, the new capacity installed decreased progressively year after year, however, the market still reaches a high level given the country size.

Together, these five leading countries or block of countries represented 74% of all installations recorded in 2018 and 74% in terms of installed capacity. This shows how the global PV market remains concentrated within a limited number of markets, however, slightly less than in previous years. This also shows the current market rebalancing, with the largest countries and largest electricity consumers taking the lead for annual installations.

Heading the top 10 countries, China, India, the USA and Japan are followed by **Australia** that installed a tremendous 3,8 GW in 2018. The country experiences a boom in utility-scale applications together with a robust demand for distributed PV systems.

FIGURE 2.5: EVOLUTION OF REGIONAL PV INSTALLATIONS (GW)



SOURCE IEA PVPS & OTHERS.

Germany (sixth globally as a country) scored the first rank again amongst European countries. It saw its annual installed capacity growing to almost 3,0 GW from 1,8 GW in 2017 and 1,5 GW in 2016, but still well below the level that was reached already in 2008. The total installed PV capacity was reaching 45,9 GW at the end of 2018.

Seventh comes **Mexico** where PV installations finally developed in 2018 after some years of slow development. In total 3,6 GW were installed, most of which were utility-scale plants under tenders.

Turkey installed 2,9 GW in 2018, again a major increase compared to previous years and thus confirming the country's potential.

Korea follows with 2,3 GW, the highest level ever for the country, with a market almost completely trusted by utility-scale applications.

The **Netherlands** are closing the top 10 of countries with 1,5 GW installed in 2018, in a booming market.

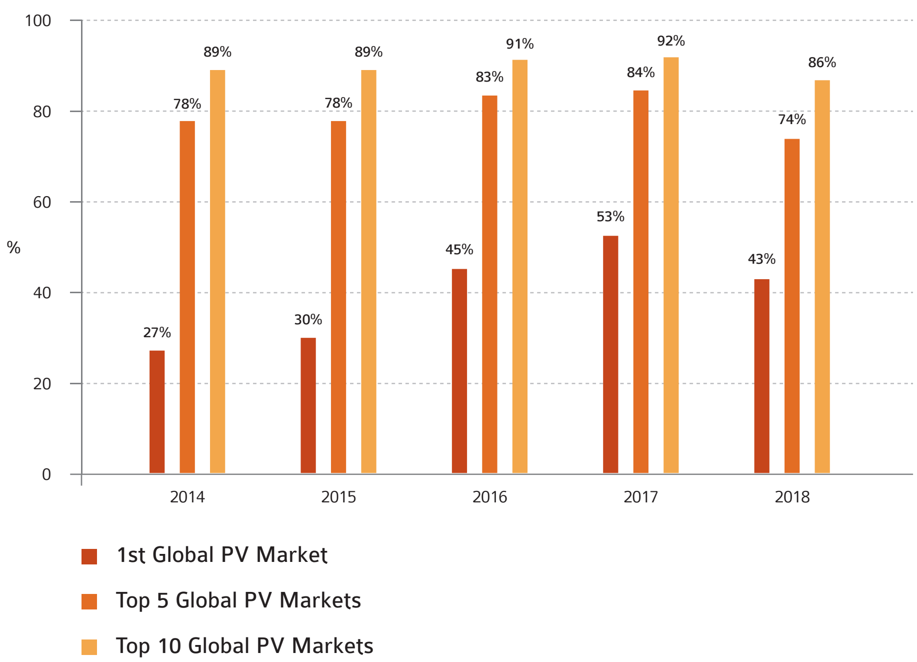
Together, these 10 countries cover 86% of the 2018 world market, a sign that the growth of the global PV market has been driven by a limited number of countries again, while others are contributing marginally. This market concentration has been fuelling fears for the market's stability, if one of the top three markets would experience a slowdown; which is exactly what happened on May 31, 2018, when China decided to control its PV market. However, as shown in figure 2.6, the market concentration steadily decreased as new markets started to emerge, this allowed a market stabilization despite the reduced contribution of China.

The level of installation required to enter the top 10 increased steadily since 2014; from 843 MW to 1,5 GW in 2018, this reflects the global growth trend of the solar market.

Some countries that reached the top 10 in the last years, such as **Brazil** (2017), **United Kingdom** (2017), **Thailand** (2016) or **Chile** (2016) and left this part of the rankings.

Behind the top 10, some countries installed significant amounts of PV. **Brazil** installed over 1 GW thanks to important policy changes, **Taiwan** (970 MW) **Egypt** (491 MW), **Chile** (596 MW), **Israel** (406 MW) and **Malaysia** (503 MW).

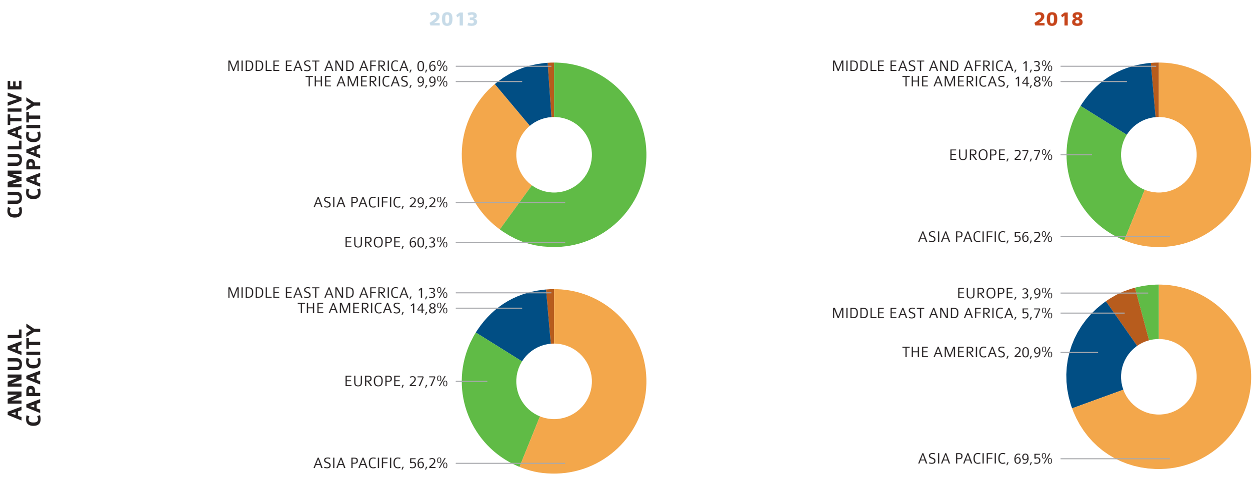
FIGURE 2.6: EVOLUTION OF MARKET SHARE OF TOP COUNTRIES



SOURCE IEA PVPS & OTHERS.

THE MARKET EVOLUTION / CONTINUED

FIGURE 2.7: EVOLUTION OF ANNUAL AND CUMULATIVE PV CAPACITY BY REGION 2013 - 2018 (MW)



SOURCE IEA PVPS & OTHERS.

A TRULY GLOBAL MARKET

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. Within the IEA PVPS countries, Austria installed 169 MW, Belgium 434 MW, Denmark installed around 91 MW despite major policy revisions in the last year, Finland installed 53 MW, France 862 MW, Italy 425 MW, Norway 23 MW, Spain 288 MW, Sweden 159 MW and Switzerland 271 MW.

In the rest of Europe, the Greece and Czech Republic had respectively 2,8 GW and 2,2 GW installed, but barely added new capacity in 2018, Romania with a cumulative capacity of 1,4 GW showed the same trend. The United Kingdom installed 291 MW, also a negligible volume compared to the capacity installed. Conversely, Portugal reached 673 MW of installed capacity, another record year. Russia and Ukraine also experienced a significant growth in 2018, reaching respectively 500 MW and 1,3 GW. The other non-IEA PVPS countries showed limited growths, both in the past as recently.

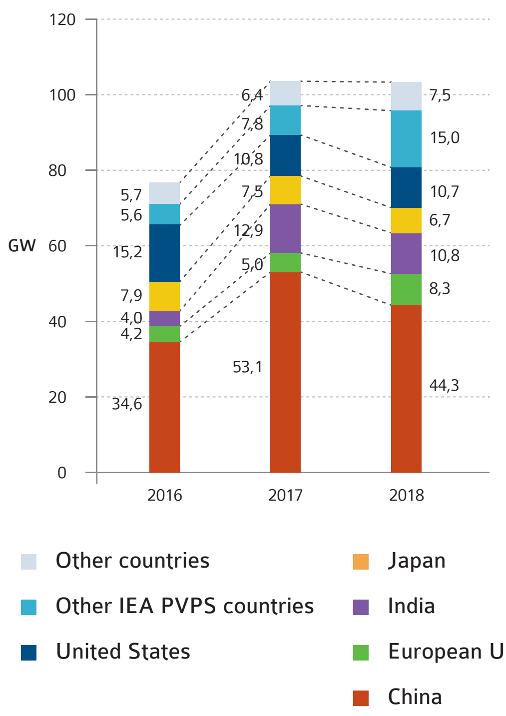
Despite a slower growth, some of the countries above have already reached high PV capacities due to past installations. This is the case for Italy that tops 20,0 GW but also for the United Kingdom with 13,0 GW, Spain with 5,6 GW, Belgium with 4,3 GW and Switzerland with 2,2 GW.

In Asia, many countries have started to implement PV policies for rooftop or utility installations or both. Malaysia installed 503 MW in 2018, due to numerous efficient support mechanisms. The island of Taiwan became a quasi GW scale market in 2018 and more is planned. The market in the Philippines remained low, following the boom of 2016 and Thailand went down again to 380 MW, with a total installed capacity of 3,4 GW. Pakistan saw its capacity expand to 2,1 GW with an estimated growth of 200 MW in 2018.

In Latin America, Chile installed 596 MW in 2018. Projects are popping up in Brazil with over 1 GW installed in 2018. Brazil lost the lead in Latin America to Mexico, that installed 3,6 GW in 2018. Mexico became the second GW-size market in Latin America, reaching a cumulative capacity of 4,1 GW. Honduras installed 391 MW in 2015, but this outcome was not repeated in the following years, the country now has an installed capacity of 511 MW. The real PV development of grid-connected PV plants has finally started and additional countries have installed dozens of MW. Among some promising prospects in the region, Peru installed close to 188 MW in 2018 and Guatemala 91 MW.

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 250 MW in 2018 and new capacity was tendered, in Abu Dhabi, 300 MW were tendered in 2018 and Dubai added 250MW capacity to the fourth phase of a GW solar park. Finally, in Africa, despite the growth of the market to around 1,2 GW in 2018, the share of the PV market in Africa remains small compared to other regions of the world. The total solar PV installed capacity at the end of 2018 in Africa reached 4 805 MW. With 2,4 GW installed in total, South Africa represents

FIGURE 2.8: 2016 - 2018 GROWTH PER REGION



SOURCE IEA PVPS & OTHERS.

TABLE 2.1: EVOLUTION OF TOP 10 PV MARKETS

RANKING	2015	2016	2017	2018
1	CHINA	CHINA	CHINA	CHINA
2	JAPAN	USA	USA	INDIA
3	USA	JAPAN	INDIA	USA
4	UK	INDIA	JAPAN	JAPAN
5	INDIA	UK	TURKEY	AUSTRALIA
6	GERMANY	GERMANY	GERMANY	GERMANY
7	KOREA	THAILAND	KOREA	MEXICO
8	AUSTRALIA	KOREA	AUSTRALIA	TURKEY
9	FRANCE	AUSTRALIA	BRAZIL	KOREA
10	CANADA	PHILIPPINES	UK	NETHERLANDS
MARKET LEVEL TO ACCESS THE TOP 10				
	675 MW	683 MW	954 MW	1 511 MW

SOURCE IEA PVPS & OTHERS.

more than the half of the African market. However, many other countries are experiencing some PV development, from Egypt (660 MW) and Algeria (519 MW) to Réunion Island (190 MW), Senegal (134 MW), Kenya (93 MW), Mauritania (86 MW), Namibia (79 MW) and Ghana (64 MW).[2]

GLOBAL TRENDS, LOCAL DYNAMICS

While large markets such as Germany or Italy have been leading the annual market installations in the past, they 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, before Japan in 2016. In 2017, India took the third spot from Japan and in 2018 the second spot from the USA. Six of the top 10 leaders in 2012 are still present in 2018 while the others have varied from one year to the next. Turkey and Brazil joined for the first time in 2017 and Mexico for the first time in 2018. 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 Netherlands entered in the top 10 in 2018 for the first time.

In 2014, only major markets reached the top 10, the end of a long-term trend that has seen small European markets booming during one year before collapsing. The Czech Republic experienced a dramatic market uptake in 2010, immediately followed by a collapse. Belgium and Greece installed hundreds of MW several years in a row. Greece and Romania scored the GW mark in 2013 before collapsing. 2014 started to show a more reasonable market split, with China, Japan and the USA climbing up to the top places, while India 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. The arrival of the Netherlands or the high numbers installed in Australia, both in the top 10, show the potential of development for other countries with larger populations and energy consumption.

The number of small-sized countries with impressive and unsustainable market evolutions declined, especially in Europe but some booming markets could experience a similar fate. For example, Honduras lost its newly acquired position in 2016 and, more recently, the Philippines and Chile entered the top in 2017 and left it in 2018. In the case of Chile, the market could be looked at as sustainable, however, with less than 1 GW a year, the threshold for the top 10 is now too high.

2 Source: *Solarize Africa Market Report.*

THE MARKET EVOLUTION / CONTINUED

In 2018, 1,5 GW were necessary to reach the top 10, compared to 843 MW in 2014, while the global PV market surged from 30 to more than 100 GW at the same time. The number of GW markets that declined in 2014 to only five grew again to ten in 2018. Some countries re-experienced growth in 2018, after several stagnation or even declining 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 2018, but their share is growing rapidly.

UTILITY-SCALE PV: THE PV MARKET DRIVING FORCE

The most remarkable trend of 2018 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. Utility-scale PV continued to develop fast and new countries appeared on the installation map.

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, such as Jordan, Tunisia or Senegal, for instance. 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 stayed stable in 2018 with more than 61 GW, compared to 63 GW in 2017 and only 56 GW in 2016. Utility-scale still represents around 62% of cumulative installed capacity but for the second time in years, distributed PV also grew significantly, up to 36 GW in 2017 and even more in 2018. However, with a stable PV market in 2018, the growth of the utility-scale segment was done detrimentally to the distributed segments.

Many countries are proposing new tenders, including France, Germany, Greece, Poland, Portugal and Spain in the EU, the UAE, Jordan and Oman in the Middle East, Brazil, Mexico, Guatemala and Nicaragua in Latin America, Senegal and Tunisia in Africa, and Nepal and Sri Lanka are the newcomers in Asia. However, more and more tenders are being launched for small-scale market segments. In 2018, several European countries organized tenders for market segments from 500 kW up to 20 MW (France, Greece and Germany for instance).

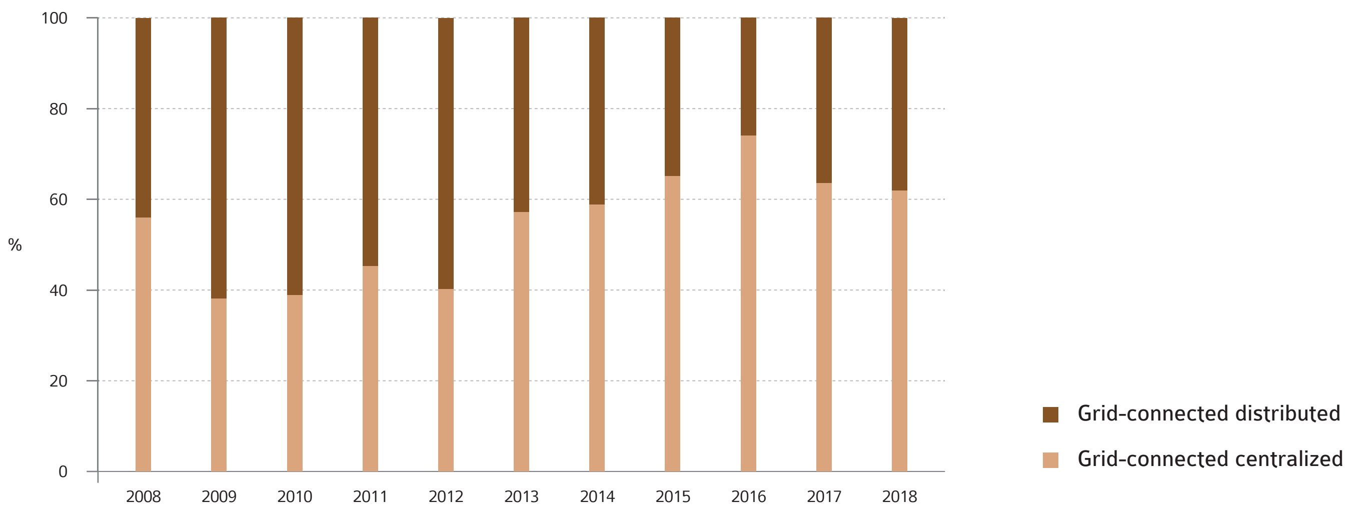
Until recently, tenders offered an alternative to unsubsidised installations due to the lack of competitiveness with wholesale market prices but constrained the market, while favouring the most competitive solutions (and not always the most innovative, unless mentioned explicitly). In 2018, Spain and Chile started to become attractive for utility-scale PV plants financed with wholesale market electricity sales only, which is expected to shape differently the PV market in the coming years. The lowest PV electricity prices signal the start of a new era where merchant PV could start to compete with policy-driven PV installations.

The competitiveness of PV also opens a promising future for new applications such as green hydrogen production, but little was realized in 2018 in that respect.

FLOATING PV: AN EMERGING MARKET SEGMENT

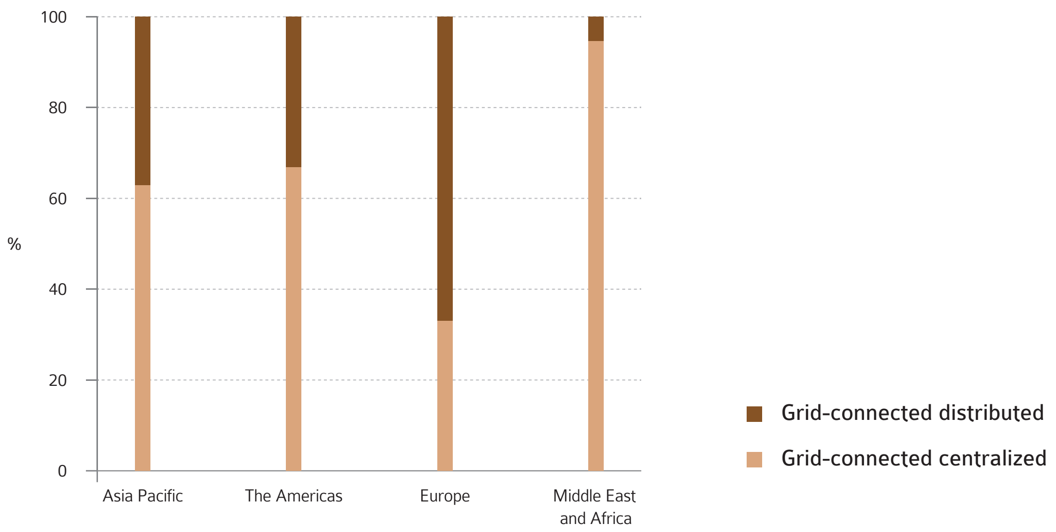
Land is scares in many countries, at least close to consumption centers, where it matters to install massively PV, and in many cases, public opinion has expressed some negative feelings towards the substantial development of utility-scale PV. Floating PV appears to be a smart alternative: installing floating PV systems on lakes, water reservoirs and even seas, allows to

FIGURE 2.9: ANNUAL SHARE OF CENTRALIZED AND DISTRIBUTED GRID-CONNECTED INSTALLATIONS 2008 - 2018



SOURCE IEA PVPS & OTHERS.

FIGURE 2.10: GRID-CONNECTED CENTRALIZED AND DISTRIBUTED PV INSTALLATIONS BY REGION 2018



SOURCE IEA PVPS & OTHERS.

develop utility-scale PV without using land. By installing PV on water reservoirs, it has been shown that PV limits evaporation. Installed on the lake of a hydropower plant, it benefits from an already existing grid connection, and reduces the system cost. China leads the floating PV market, but other Asian countries like Korea or Singapore, but also France, the Netherlands and more had either operational installations or research ones at the end of 2018 and more is being developed in 2019. While the total installed capacity reached 1,4 GW at the end of 2018, the development speed increased, with China leading the pace. From all market niches, floating PV is the one developing the fastest.

AGRI-PV: DUAL USE WHICH COULD EMERGE FAST

The development of PV on agricultural land is a given but, in most cases, crops have been replaced by PV and while some counterexamples exist, the use of the land has mostly shifted towards electricity production. Agri-PV proposes a different perspective with the possibility to use PV as an additional source of revenues for farmers, completing their agricultural business. By positioning PV systems above the crops or plants, the system can allow to grow different kind of crops with a reduced solar insulation, allowing a better development in sunny regions, and possibly new business models, such as recovering of damaged crops for instance, or different crops which would not have been profitable in some regions. This dual use imposes a different kind of PV systems, which can in some case change their position, from horizontal to vertical and allow either maximum PV production or maximum crop production depending on the weather conditions. Defining Agri-PV could be difficult and most existing plants on agricultural land could hardly be qualified as such. We will define Agri-PV in general as a PV plant which allows a real double use of the land, for agriculture and for PV, without putting the emphasis completely on the PV plant.

PROSUMERS, EMPOWERING CONSUMERS

Once purely driven by financial incentives, prosumers develop thanks to various schemes based on the concept of self-consumption. Such schemes have been identified in many countries with various implementations and success. While established markets such as Belgium or Denmark are moving away from net-metering, 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 recently, mainly in the Middle East (Bahrain and Lebanon) and in Latin America (Chile, Peru, Ecuador) but also in Asia (some states in India, Indonesia, Thailand). On the other hand, electricity prices are still being maintained artificially low in some countries. Subsidies for fossil fuels are still a reality and reduce the attractiveness of solar PV installations, also in market segments involving self-consumption. The PV market tends to grow quickly when electricity prices increase. In Brazil, the distributed segment grew with 372 MW in 2018 due to rising electricity prices. Rising electricity prices in Australia are also responsible for the massive uptake of solar PV by residential consumers.

However, the main trend goes in the direction of self-consuming PV electricity in most of the countries, often with adequate regulations offering a value for the excess electricity. This can be

THE MARKET EVOLUTION / CONTINUED

done with a FiT or more complex net-billing. On the other hand, the move towards pure self-consumption schemes can create temporary market slowdowns, especially if the transition is abrupt. However, if the market conditions are favourable and the market regains confidence, self-consumption can become a market driver.

The distributed market has been oscillating around 16-19 GW from 2011 to 2016, until China succeeded in developing its own distributed market: it allowed the distributed PV market to grow significantly to more than 36 GW globally in 2017 and stabilized in 2018 with again more than 36 GW.

Several countries promote collective and distributed self-consumption as a new model for residential and commercial electricity customers. This model allows different consumers located in the same building or private area (collective self-consumption), or in the same geographical area which requires to use the public grid (distributed or virtual self-consumption), to share the self-generated electricity; thereby unlocking access to self-consumption for a wide range of consumers. Such regulation, if well implemented, will allow development of new business models for prosumers, creating jobs and local added value while reducing the price of electricity for consumers and energy communities. These models of production could also positively impact grid integration of PV systems by enhancing adequacy between production and demand. In the case of "virtual (or distributed) self-consumption", the prosumers are not grouped behind a meter. We will call "virtual (or distributed) self-consumption", the case where production and consumption can be compensated at a certain distance, without paying all grid costs.

BIPV: WAITING FOR THE START

The BIPV market remains a niche which can hardly been estimated properly. With multiple business models, different incentives, all kind of buildings or infrastructure (including roads), the BIPV market cannot easily be estimated. From tiles and shingles for residential roofs to glass curtail walls and more exotic façade elements, BIPV covers different segments with different technologies. Depending on the definition considered, the BIPV market ranges from 100 MW to 1 GW per year, while the difference between custom-made elements and traditional glass-glass modules can be difficult to assess. The market is also split between some industrial products such as prefabricated tiles (found in the USA and some European countries for instance), to custom-made architectural products fabricated on demand.

OFF-GRID MARKET DEVELOPMENT

Numbers for off-grid applications are generally not tracked with the same level of accuracy as grid-connected applications. The off-grid and edge-of-the-grid market can hardly be compared to the grid-connected market. The rapid deployment of grid-connected PV dwarfed the off-grid market. Nevertheless, off-grid applications are developing more rapidly than in the past, mainly thanks to rural electrification programs mainly in Asia and Africa but also in Latin America.

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; around 2 MW in Sweden for instance. Regulations constraining self-consumption have led to residential homeowners in 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, 37 MW of off-grid systems have been installed in 2018, bringing the total to 284 MW.

Japan has reported 2 MW of new off-grid applications in 2018; bringing the installed capacity around 173 MW, mainly in the non-domestic segment.

In some countries in Asia and in Africa, off-grid systems with back-up represent an alternative in order to bring the grid into remote areas. Two types of off-grid systems can be distinguished:

- Mini-grids, also termed as isolated grids, involves small-scale electricity generation with a capacity between 10 kW and 10 MW. This grid uses one or more renewable energy sources (solar, hydro, wind, biomass) to generate electricity and serves a limited number of consumers in isolation from national electricity transmission network. Back-up power can be batteries and/or diesel generators.
- Stand-alone systems, for instance solar home systems (SHS) that are not connected to a central power distribution system and supply power for individual appliances, households or small (production) business. Batteries are also used to extend the duration of energy use.

This trend is specific to countries that have enough solar resources throughout the year to make a PV system viable. In such countries, PV has been deployed to power off-grid cities and villages or for agricultural purposes such as water pumping installations. 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.

Bangladesh installed an impressive amount of these off-grid Solar Home Systems (SHS) in recent years. More than four million systems were already operational in 2017 and the country wants to finance 6 million in total by 2021. The programme brought electricity to more than 18 million Bangladeshis who previously used kerosene lamps for lighting.

India had foreseen up to 2 GW of off-grid installations by 2022, including twenty million solar lights in its National Solar Mission. In March 2019, the central government approved a new programme to help farmers install solar pumps and grid-connected solar power projects. The programme aims to add a solar capacity of 25 GW by 2022. 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 most developed countries in Europe, Asia or the Americas, this trend remains unseen and the future development of off-grid applications will most probably only be seen 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 West Indies have already imposed specific grid codes to PV system owners: PV production must be forecasted and announced in order to better plan grid management.

THE ENERGY STORAGE MARKET

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 ratio of PV plants. Despite their decreasing cost, such solutions are not yet economically viable in all countries and market segments. However, the adoption of batteries is on the rise as more and more consumers are willing to maximise their self-consumption. More large-scale PV plants are being built in combination with batteries, those can be used to stabilize grid injection and, in some cases, to provide ancillary services to the grid.

While 2015 was a year of significant announcements regarding electricity storage, in comparison, 2016 and 2017 delivered little progress. In 2018, the market was still limited to some specific countries that have implemented specific incentives. However, the cost of storage is pursuing its steep decline and storage is becoming more attractive in a growing number of markets. Amongst the countries that have issued laws to incentivize storage, Germany extended incentives for battery storage in PV systems to 2018, Italy has a tax rebate and some cantons in Switzerland have subsidy schemes. In Germany, the 100 000 installations threshold was reached in June 2018.

In 2018, Australia confirmed its place as a leading country for batteries. Over 20 000 residential energy storage installations took place in 2017 and this number jumped to 33 000 in 2018. Together with some large-scale installations, the market reach over 300 MWh.

Despites impressive numbers, the large part of batteries sold are used for transportation in EVs. Stationary storage remains the exception and volumes remain small. However, the rapid development of electric mobility is driving battery prices down much faster than any could have expected in the stationary market alone. This could give a huge push to the development of storage as a tool to ease PV installations in some specific conditions. In addition, new requirements for grid integration in tenders tend to favour the use of stationary batteries in utility-scale plants, but this trend would require some more years to be clearly visible.

PV could make EVs greener faster

The shift from fossil fuels to electricity for individual transportation and especially cars and light-duty vehicles is a necessary step towards the decarbonization of the transport sector. However, the real emissions of GHG for EVs depend on the power mix used to charge cars. In countries with a power mix heavily relying on fossil fuels, the emissions will remain higher than in countries with a renewable or carbon-free mix.

In that respect, some initiatives popped up in the recent months in Europe to connect the fast development of the EV market to renewables and especially PV. The idea to propose to the automotive industry to decarbonize completely electric vehicles would imply to sell renewable energy contracts or easier, shares in PV plants, when an EV is brought to the market. This idea, which would make EV almost GHG-free, started to develop in the PV industry when these lines were written.

From PV to VIPV

With its distributed nature, PV fits perfectly with EV charging during the day when cars are stationed in the offices parking or at home. Such slow charging is also highly compatible with distribution grid constraints. Finally, the integration of PV in the vehicles themselves, the so-called VIPV, also offers opportunities to alleviate the burden on the grid, increase the autonomy of EVs and connects the automotive and PV sectors. 2018 and 2019 showed announcements from several manufacturers, especially in Japan and Korea, but also Germany and the Netherlands, for VIPV systems integrated in EVs. The Task 17 of IEA PVPS deals with this fast-emerging subject.

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 2018, 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. That level would rise to 12 percent for 2020. In parallel, countries such as Britain, India, France and Norway have announced that fossil-fuelled cars will be banned from the market from 2030 or 2040. In 2018, Italy established a new set of regulations aimed at accelerating the adoption of electric cars. At the same time, a new tax was introduced on internal combustion engines (ICE): the higher the emissions, the higher the tax. Furthermore, the European Investment Bank is working alongside the Italian utility Enel to install about 14 000 charging stations for electric vehicles throughout Italy, over the next five years.

Most automotive manufacturers have announced plans to expand their portfolio of electric-powered vehicles. With more than 1,2 million electric vehicles sold in the world in 2017 and more than 2 million during the year 2018, the automotive sector is moving rapidly towards connecting to the electricity industry. Representing half of the vehicles sales, China is leading the global market.

Another remarkable trend concerning electric mobility is the rise of electric two wheelers. In Germany, 40 000 electric "cargo-bikes" were sold in 2018; twice as many as in 2017. E-bike popularity has been growing recently in some European countries, whereas in countries such as China and India, e-scooters have been more successful and are expected to further lead the EV market.

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.

PV DEVELOPMENT PER REGION AND SEGMENT

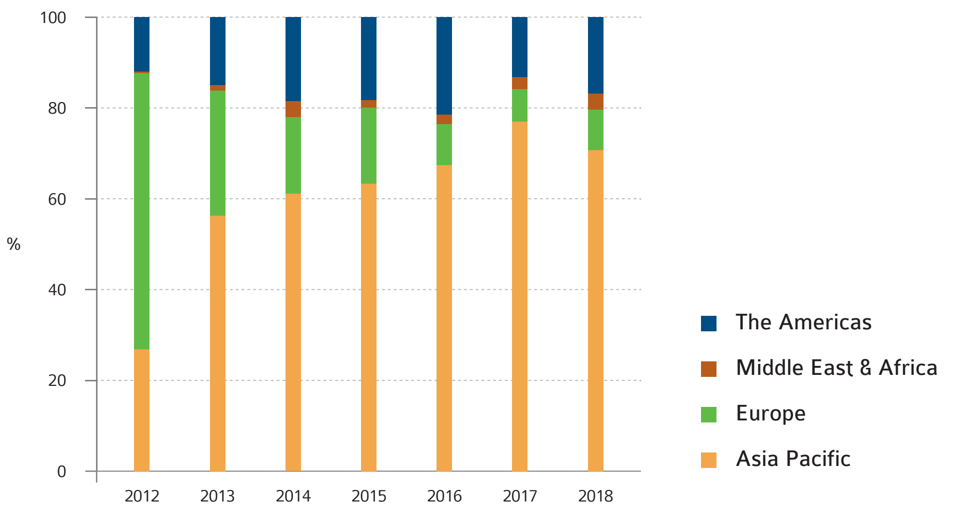
Globally, centralized PV continued to represent more than 62% of the market in 2018, mainly driven by China, the USA, and emerging PV markets. 2017 and 2018 saw again remarkable progress in terms of PV electricity prices through extremely competitive tenders. Although renewed competitive tenders contributed to the utility-scale market, distributed PV also increased significantly in 2017 and 2018, with more than 36,2 GW installed in 2018; with 20,9 GW from China alone.

Initially 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, tenders that are making PV electricity even more attractive in some regions. However, some policies were implemented recently in emerging markets to incentivize rooftop installations and tenders for rooftop installations are being organized in several historical markets.

Figure 2.11 illustrates the evolution of the grid-connected PV installations share per region from 2012 to 2018.

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 around 1 GW until 2004, the market started to grow very fast, thanks to European markets in 2004. In 2008, Spain fuelled market development while Europe as a whole achieved more than 80% of the global market: a performance repeated until 2010.From around 1 GW in 2004, the market came doubled in 2007 and reached 8 GW and 17 GW in 2009 and 2010.

FIGURE 2.11: SHARE OF GRID-CONNECTED PV MARKET PER REGION 2012 - 2018



SOURCE IEA PVPS & OTHERS

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 2018, with the share of the Asia-Pacific region growing from 26% to more than 70%, whereas the European share of the PV market went down from 61% to around 9% in six years.

The share of the PV market in the Middle East and in Africa remained stable and relatively small compared to other regions of the world up to 2017. However, 2018 seem to be a turning point with the growth of the South African market and the numerous projects in the Middle East.

PV PENETRATION PER CAPITA

Figure 2.12 shows PV penetration per inhabitant at the end of 2018, in watts per inhabitant.

Germany has the highest capacity per inhabitant by a large margin, at 548 W/inhab. Japan is second with 444 Wp/inhab. Australia comes next with 438 W/inhab, coming from the 4th place in the ranking of 2017, it now exceeds the installed capacities per inhabitant in Belgium (380 W/inhab). Italy remains at the 5th place with 325 W/inhab, followed by the Netherlands and Switzerland, both around 256W/inhab, then Malta, Greece, Luxembourg and Czech Republic, all above the 200 W/inhab. UK and USA come next showing values slightly below 200 W/capita (197 and 191 W/inhab respectively).

THE AMERICAS

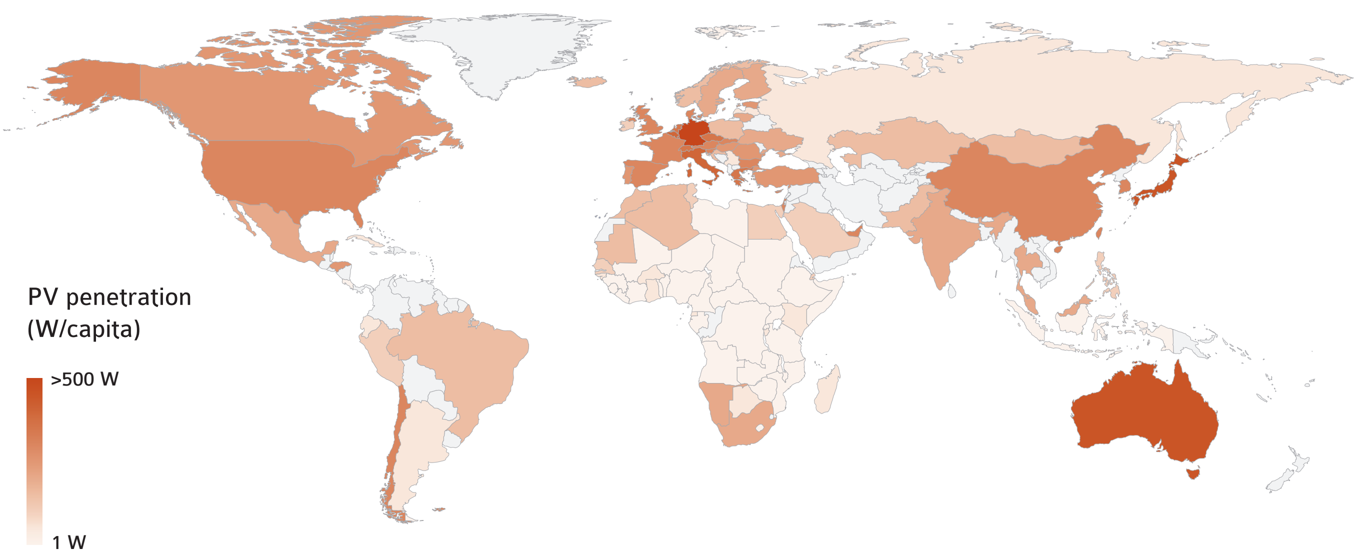
The Americas represented 16,6 GW of installations and a total cumulative capacity of 75,22 GW in 2018. If most of these capacities are installed in the USA, several countries have started to install PV in the central and southern parts of the continent; especially in Chile and Honduras in 2015 and 2016 and more recently Mexico and Brazil.

CANADA

FINAL ELECTRICITY CONSUMPTION 2018	253	TWh
HABITANTS 2018	37	MILLION
AVERAGE YIELD	1 150	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	161	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	3 095	MW_{DC}
PV PENETRATION	0,8	%

As of December 31, 2018, the cumulative grid-connected PV capacity in Canada was approximately 3,1 GW. This represented a growth of approximately 5,5% over the previous year corresponding to a capacity increase of 161 MW. Approximately 96% of installed PV capacity was in Ontario with growth in this province catalysed by the Green Energy and Green Economy Act initiated in 2009. Canada's centralized PV capacity (system size greater than 0,5 MW) consisted of 165 systems with a total capacity of approximately 2,0 GW. The country's distributed capacity (system size less than 0,5 MW) consisted of 43 671 systems with a total capacity of approximately 1,09 GW. Only grid-connected systems

FIGURE 2.12: PV PENETRATION PER CAPITA IN 2018



SOURCE IEA PVPS & OTHERS.

THE AMERICAS / CONTINUED

were surveyed, although off-grid systems do make up a small but negligible amount. Beyond Ontario, cumulative PV capacity is increasing in Alberta (61 MW), Saskatchewan (22 MW), British Columbia (14 MW), and Québec (6 MW).

In terms of future outlook, Canada's PV growth in the coming years will depend critically on provincial and federal government policies. Ontario's contribution to yearly capacity installation is declining as its Feed-in-Tariff (FiT) programs are replaced by net metering and distributed capacity expansion. Ontario's microFiT programme for system sizes less than 10 kW ended in 2018. The FiT program, which had several project size tiers, applied to systems larger than 10 kW and concluded in 2016. The Large Renewable Procurement programme replaced FiT for project sizes greater than 500 kW 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 2019. Nevertheless, Ontario's PV capacity growth in 2018 was down 80% as compared to its peak in 2015. 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 regions increase their installation rates to make up for Ontario's shortfall. Although Canada's federal government announced a price on carbon for the entire country, from 10 CAD per tonne in 2018 to 50 CAD per tonne 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 2018	73	TWh
HABITANTS 2018	19	MILLION
AVERAGE YIELD	1 699	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	596	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	2 371	MW_{DC}
PV PENETRATION	5,5	%

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 596 MW installed in 2018, 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 neighbouring northern regions.

At the end of 2018, more than 2,3 GW of PV were operational in the country, the high yield resulted in a large PV electricity production.

The country has the particularity to be extremely long and was divided into 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 a small share of the 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 21,5 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 21,5 MW of solar PV rooftop installations were installed at the end of 2018.

MEXICO

FINAL ELECTRICITY CONSUMPTION 2018	270	TWh
HABITANTS 2018	126	MILLION
AVERAGE YIELD	1 708	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	3 617	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	4 102	MW_{DC}
PV PENETRATION	2,6	%

Around 3,6 GW of PV systems were installed in Mexico in 2018, increasing the total capacity in the country to 4,1 GW. While most of past installations were rooftop PV systems installed under the net-metering scheme until 2015, utility-scale started to grow slowly in 2016 and accelerated in 2018. To date, the many tenders granted in the utility-scale segment have been either already installed or in development as expected but the installation numbers are growing and 2018 say for the first time Mexico becoming a GW-scale market appearing on the global PV map.

39 utility-scale plants were operational at the end of 2018, representing 3,5 GW while distributed PV represented 570 MW with more than 85 000 installations.

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 neighbouring 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 2018	3,971	TWh
HABITANTS 2018	327	MILLION
AVERAGE YIELD	1 437	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	10 680	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	62 498	MW_{DC}
PV PENETRATION	2,3	%

In 2018, the PV annual installed capacity in the USA stabilized around 10,7 GW. Consequently, the PV cumulative capacity has reached 62 GW at the end of the year 2018, maintaining the USA at the second rank of all countries. The majority of the 2018 installations developed in the utility-scale segment with 6,2 GW (compared to 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. Distributed PV represented 4,5 GW in 2018, a stable number compared to 2016 and 2017.

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 MW. 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 Programme that issues incentives between 0,32 and 0,45 USD/Wh according to the size of the implants. Moreover, other 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 AMERICAS / CONTINUED

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.

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.

Regarding 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. Most 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.

OTHER COUNTRIES

Several countries in Central and South America have continued developing in 2018, below the major trends and developments are being highlighted.

Brazil finished the year 2018 with 2,3 GW of PV installed capacity, most of the newly installed capacity came from new utility scale projects (677 MW). Nevertheless, distributed generation grew at a higher pace during 2018, as a total of 372 MW were installed (up to 5 MW, which is a significantly higher limit that the one used on this report). This increased growth is a direct result from the net-metering system put in place in Brazil. The government has set up an 8,6 GW target for PV in 2027. Several tenders were launched in 2017 and 2018, therefore more utility-scale PV awarded through auctions is expected to be built in the coming years. As the net-metered installations should continue to grow, Brazil's PV potential might continue develop 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 is starting to take off, with 191 MW installed in the country at the end of 2018. Most of the new installations were large-scale projects and more are expected to start commercial operation in 2019. 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" programme 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, a 180 MW utility-scale plant have been installed in 2018, the project was awarded a PPA following a tender in 2016. 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.

Several programmes related to rural electrification are in place for a few years and since 2018 a net-billing scheme for installations up to 200 kW has been introduced, and a scheme for projects up to 10 MW as well.

2015 was a decisive year for the PV market in Honduras with 388 MW installed, followed by only 45 MW in 2016, a few MW in 2017 and around 58 MW in 2018. There is no evidence suggesting that similar measures for PV development will be introduced again in the mid-term, however, the country invested in more than 2 700 Solar Home Systems (SHS) to power villages, schools and municipalities.

In Colombia, 2018 saw the start of the building of an 80 MW plant and more is done for rural electrification. The 2022 objectives of the government for renewables are set at 1 500 MW, to achieve this goal a tender of 1 GW renewable power should be launched in 2019. In 2018, the country issued new regulation for distributed solar generation; a net-metering system and the possibility to sell surplus power to the National Interconnected System were introduced.

Several other countries in Central and Latin America have put support schemes in place for PV electricity, and tenders are announced for 2019 in countries such as Ecuador and Guatemala. Other countries, such as Uruguay, Bolivia, have installed several dozens of MW in the last years 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 72 GW in 2018 and more than 295 GW are producing PV electricity. Despite the slowdown in the Chinese market, this region again experienced a booming year with 34% as the region annual growth rate.

AUSTRALIA

FINAL ELECTRICITY CONSUMPTION 2018	259	TWh
HABITANTS 2018	25	MILLION
AVERAGE YIELD	1 531	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	3 775	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	10 953	MW_{DC}
PV PENETRATION	6,8	%

After having installed between an average of 950 MW per year for the last five years, Australia installed a new record 3,4 GW in 2018 after significant growth in the large-scale solar sector. The country now has more than 11,0 GW of PV systems installed and commissioned (including known off-grid systems). More than 2,0 million buildings now have a PV system; an average penetration over the 20% in the residential sector, with peaks up to 70%.

In 2018, the Australian market was underpinned by strong growth in the large-scale solar sector, with 2,26 GW installed and commissioned; a ten-fold increase from 2017. There was growth in every other sector, with the residential segment reaching 1,0 GW and small-commercial (10-100 kW) reached 509 MW. The large commercial and industrial sized systems in the 100-5 000 kW range more than doubled to 117 MW. PV contributed to 5,5% of the total electricity consumption in 2018.

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 2018.

Large-scale solar installations commissioned in 2018 benefited from capital support and generation credits through the LRET. A strong pipeline of projects exists based on reverse auctions and commercial power purchase agreements.

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 22 000 installations of grid-connected batteries combined with PV systems totalling 190 MWh in 2018, and a total installed volume of 50 710 residential batteries installed.

CHINA

FINAL ELECTRICITY CONSUMPTION 2018	6 308	TWh
HABITANTS 2018	1 393	MILLION
AVERAGE YIELD	1 300	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	44 260	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	175 400	MW_{DC}
PV PENETRATION	3,6	%

With 44,26 GW installed in 2018, the Chinese PV market has once again experienced a significant level of installations, but significantly lower than the heights reached in 2017. With these installations, Chinese cumulative PV capacity confirmed its first rank with 175 GW at the end of 2018. 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 year 2018 was marked by a significant policy change which happened in 31st May 2018 and the so-called 5.31 issue had significant consequences on the Chinese PV market development. In order to better control market development and to establish sustainable market, as well as control the burden for subsidy that would result excessive retail electricity prices, the Chinese government decided to frame PV development. This led to a major decrease of components prices on international markets and a clear decrease of the final market size in China.

While the utility-scale segment continued to dominate the Chinese PV market with 23,3 GW installed in 2018, its share diminished significantly in 2018. From 2013 until 2016, this segment

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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 and 2018 amounted to around 20 GW, a record-high number, including some hundreds of MW of floating and agricultural PV.

Finally, 114 MW of storage were added in China during the year 2018.

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 2018:

- 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 (Feed-in tariff) 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 Programme 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" programme 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 with requirement for PV module efficiency and output capacity
- During 2018, driven by the "front runner" program, several 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 sixth year in a row in 2018. 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 2,59% of the total electricity consumption. NEA is aiming to establish grid parity and planning the transition to subsidy-free PV market besides the PV Poverty Alleviation Program.

JAPAN

FINAL ELECTRICITY CONSUMPTION 2018	906	TWh
HABITANTS 2018	127	MILLION
AVERAGE YIELD	1 050	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	6 662	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	56 162	MW_{DC}
PV PENETRATION	6,8	%

In 2018, Japan installed 6,7 GW of new PV capacity, a 12% decrease from the level of 2017. The country has reached a total installed PV capacity of 56,2 GW, making it the third country in the world after China and the USA. After having reached close to 11 GW in 2015, the market declined at a lower level in 2018 due to FiT level changes, but still at an impressive level.

With the start of the FiT programme in July 2012, the market for public and 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 PV markets in the world in the first decade of this century, most installations took place after the implementation of the FiT programme.

While the PV market in Japan first developed in the residential rooftop market, 2018 has seen again a major deployment of utility-scale plants: such systems represented 3,2 GW in 2018, accounting for 48% of the market. The commercial segment reached 2 GW in 2018, followed by the commercial market with close to 1 GW and the residential market with 628 MW. BIPV installations represented around 30 MW and off-grid applications 2 MW.

Feed-in Tariff

The FiT programme 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 2018, a tendering scheme started for PV plants (2 MW and above) under the FiT scheme. From April 2019, more than 500 kW is subject to tender. The cost of the FiT is shared among electricity consumers with some exceptions for electricity-intensive industries. This scheme has triggered the important development of the Japanese PV market seen in last years.

In 2018, the FiT levels were adjusted downwards with a certain impact on the PV market so far. However, the rapid price decline of PV modules indicates that the margins of installers and developers are also declining. Capital subsidies are also available for systems 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 2018 starting April 2018, 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

The market for BIPV remains relatively small compared to the BAPV market and around 30 MW were installed in 2018. However, Japan is preparing for the uptake of BIPV. NEDO started a study project named "study on BIPV" in 2017 and continued it in 2018, in order to collect information and identify issues for the commercialization of BIPV systems, whereas 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 programme 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 a high level of control.

For some PV power plants, mainly installed in the service area of Hokkaido Electricity Power Company (HEPCO), utility-scale storage batteries were installed to meet the requirement for grid connection contracts.

KOREA

FINAL ELECTRICITY CONSUMPTION 2018	563	TWh
HABITANTS 2018	52	MILLION
AVERAGE YIELD	1 314	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	2 265	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	8 099	MW_{DC}
PV PENETRATION	2,2	%

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 2 265 MW in 2018, after having installed 1 362 MW in 2017.

Utility-scale PV plants accounted for around 1 897 MW of the installed capacity in 2018. Distributed PV systems amounted to around 14% 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 2018, the total installed capacity reached 8,1 GW. PV contributed to 1,8% of the total electricity consumption in 2018.

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 "Solar Lease 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 2019, the Third Energy Master plan was announced which aims at supplying 30~35% of the electricity generation by renewable sources by 2040.

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 21 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 (5 years for the period of 2018-2022) subsidy measure was 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 that merged the existing 100 000 rooftop PV system installation program, and it aims at constructing one million green homes utilizing PV as well as solar thermal, geothermal, small-size wind, fuel cell and bioenergy until 2020. In general, single-family houses and multi-family houses including apartments can benefit from this program. The Government provides maximum 60% of the initial PV system cost for single-family and private multi-family houses, and maximum 100% for public multi-family rent houses. The maximum PV capacity allowed for a household is 3 kW. In 2018, total 77 776 kW PV systems at 113 652 sites were installed under this program.

Building Subsidy Programme

The Government supports up to 50% of the installation cost for PV systems (below 50 kW) in buildings excluding private homes. In addition, the KEA supports maximum 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. In 2018, total 16 872 kW PV systems at 733 sites were

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installed under this program. Various grid-connected PV systems were installed in schools, public facilities, welfare facilities as well as universities.

Regional Deployment Subsidy Programme

The Government supports up to 50% of installation cost for NRE (including PV) systems owned or operated by local authorities. In 2018, 17 871 kW PV systems at 374 sites were supported from this program.

Public Building Obligation Programme

The new buildings of public institutions, the floor area of which exceeds 1,000 m2, are obliged by law to use more than 24% (in 2018) of their total expected energy from newly installed renewable energy resources. Public institutions include state administrative bodies, local autonomous entities, and state-run companies and institutions. In 2018, 71 577 kW was installed under this scheme. The building energy mandate percentage will increase up to 30% by 2020.

Solar Lease Programme

In 2013, MOTIE (through KNREC) introduced this new scheme to promote PV deployment and launched a few demo projects for 60 detached houses. The Solar Lease programme fully began from 2014, and it is designed in such a way that the private companies take care of installations and maintenance without support from the Government, while consumers pay the leasing fee. Household owners of using more than 200 kWh/month (monthly average in the recent one-year period) can apply for this program. Owners pay PV system leasing fee (monthly maximum: 70 000 KRW) which is on the average less than 80% of the typical electricity bill) for minimum 7 years and can use the PV system with no initial investment and O&M cost for the leasing period. PV leasing companies recover the investment by earning PV leasing fee from the households and selling REP (Renewable Energy Point) to RPS obligators with no multiplier. Leasing fee, lease period and REP price are properly set to motivate the participation of PV leasing companies and consumers. The maximum PV capacity allowed for a household is 3 kW for houses of consuming 200~599 kWh electricity monthly average and maximum 9 kW for houses of consuming 600 kWh or higher electricity monthly average. In 2018, 21 115 kW PV systems at 19 077 sites were installed under this program.

Hybrid Installation Subsidy Programme for NRE

This is a new NRE subsidy programme started in 2013. A consortium led either by local authority or public institution with NRE manufacturing companies and individuals can apply for this program. 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 for this program, thus the optimal integration of various NRE resources (PV, wind, electricity and heat) and the complex between areas (home, business and public) are primarily considered to benefit from this program. Total 25 574 kW PV systems at 6 275 sites were installed in 2018 under this program.

MALAYSIA

FINAL ELECTRICITY CONSUMPTION 2018	144	TWh
HABITANTS 2018	32	MILLION
AVERAGE YIELD	1 416	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	503	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	858	MW_{DC}
PV PENETRATION	0,7	%

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 2018, the PV market in Malaysia was driven mainly by the Large-Scale Solar (LSS) and Net Energy Metering (NEM) policy schemes. Although PV was introduced under the Feed-in Tariff (FiT) policy from 2012 to 2017, it was transferred to the LSS and NEM schemes. The newly installed PV capacity amounted to 503 MW In detail, 26,74 MW came under off-grid capacity; decentralized PV installation was 69,27 MW with contribution by SELCO, lastly, the centralized capacity comprised of the FiT and LSS schemes and they amounted to 313,72 MW. The cumulative installed capacity in Malaysia topped 858 MW at the end of 2018, of which ground-mounted PV is 519 MW, followed closely by rooftop PV applications of 303 MW and off-grid PV at 35,6 MW.

In May 2018, Malaysia witnessed a significant change of government. The new government has demonstrated its commitment to reduce the country's GHG footprint by having a renewable energy target of 20% in the national installed capacity mix by 2025 and this target includes hydro of installed capacities up to 100 MW. Blessed by ample sunshine throughout the country, the estimated PV potential in Malaysia is 268,9 GW – of which ground mounted is around 210,2 GW, rooftop is 42,2 GW and floating is 16,5 GW. The Ministry of Energy, Science, Technology, Environment, and Climate Change (MESTECC) and its agency - The Sustainable Energy Development Authority (SEDA) Malaysia is now developing a Renewable Energy Transition Roadmap (RETR) 2035 which is due for completion by the end of 2019. The roadmap will provide strategies and action plans to achieve the 20% RE target by 2025 and the various RE scenarios in 2035.

The solar potential in Malaysia will be harvested through the utility-scale LSS scheme and rooftop solar PV applications. The LSS contracts are offered through open bidding exercise to drive down the cost of PV electricity as seen in other countries. At the distribution level, the existing NEM scheme will be enhanced in 2019 by the Ministry in such a way that the NEM scheme will be compensated on a "one-on-one" energy offset instead of the existing "Net billing" mechanism: This would mean that every 1kWh exported to the grid will be offset against 1 kWh consumed from the grid at the official tariff.

Malaysia is one of the key hubs for PV manufacturers in the world. This starts as early as 2007 when First Solar set up their thin-film CdTe PV manufacturing plant in Kulim, Kedah. Since then other renowned international PV brands such as SunPower, Hanwha Q-Cells, and China's LONGI, JA Solar and Jinko Solar have chosen Malaysia as their manufacturing base.

THAILAND

FINAL ELECTRICITY CONSUMPTION 2018	194	TWh
HABITANTS 2018	69	MILLION
AVERAGE YIELD	1 522	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	380	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	3 436	MW_{DC}
PV PENETRATION	2,7	%

The PV market increased significantly in Thailand with 380 MW that have been installed in 2018 compared to 251 MW in 2017, down from the GW installed in 2016. Most installations developed in 2018 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 2018, the cumulative grid-connected PV capacity reached close to 2,9 GW and 36 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 2018. 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 programme 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 centres, 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" programme has been implemented. Its target has been set at 100 MW for households and buildings or factories with electricity consumption during daytime. Applicants can feed in electricity into to the grid without any compensation from government, in order to promote local self-consumption.

The PV rooftop pilot programme 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 totalling 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 programme 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

In 2018, Asia stayed in first place in terms of new PV installations, as more Asian countries have witnessed PV development. Several countries present interesting features that are described below.

India, with more than 1,4 billion inhabitants has been experiencing severe electricity shortages for years. Powered by various incentives in different states, the Indian market doubled year after year between 2014 and 2017. In 2018 it slightly decreased to 10,8 GW due to to uncertainties around trade cases, module price fluctuations and PPA renegotiations. Some policy changes such as tariff ceilings and safeguard duties in combination with a falling rupee also impacted the tendering procedures in 2018; several tender procedures found very few bidders and even not enough takers in some cases. These measures already created a market slowdown in 2018 and are expected to further impact the market development in 2019.

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.

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 federal government in India for PV is obvious, especially now that the government raised its renewables ambition to 225 GW towards 2022. 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.

The Government of Bangladesh has been emphasizing the development of solar home systems (SHS) and solar mini grids 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. 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

ASIA PACIFIC / CONTINUED

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 Programme and several announcements have been made, which remains to become concrete: 20 MW of utility-scale PV was operational begin of 2019 and several projects are in the pipeline. The country targets 3,2 GW of renewables by 2021, out of which 1,7 GW of PV. In total, more than 325 MW were operational begin of 2019. In December 2018, the cabinet committee on public procurement under the government agreed to purchase electricity from PV power plants totalling 227 MW at the rate of around US$0.1105 per kWh for 20 years. Other plans of utility scale projects including 5 GW plans by UAE firm are announced in 2019 so that utility scale market is expected to take off.

In 2014, Indonesia put in place a solar policy which has been adapted in 2017 with the introduction of a cap reflecting the regional electricity supply costs. This change was expected to trigger some accelerated market development as it would lower the costs for the state-owned utility. However, a following order issued in February 2018 has allowed to negotiate FiT tariff level with IPPs, independent power producers. Thus, until now, the FiT programme did not seem effective to catalyse the full-scale growth of the PV market. In November 2018, Minister of Energy and Mineral Resources (MEMR) issued rules for rooftop PV systems. Under the rule, surplus power can be sold at the 65% of the value of electricity charge to PLN, the Indonesian national power company. While uptake of the rooftop market is expected, local stake holders requested simplification of procedures.

A plan to develop 500 MW hybrid system (solar PV, wind, energy storage and genset) of which about 250 MW will be solar PV has been under discussion since 2012. The first 50 MW of solar capacity are expected to come online in 2019 while 2018 installed capacity was around 1 MW.

Indonesia has the target to procure 23% of its energy mix from renewable sources by 2025.

In 2018, Taiwan installed about 1 GW after having installed 522 MW in 2017, 369 MW in 2016, 227 MW in 2015 and 223 MW in 2014. The total installed capacity at end of 2018 is estimated to be around 2,4 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, which 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 favour 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 500 MW in 2018 and it is estimated that at least 2,4 GW have been installed so far. A FiT has been introduced for utility-scale PV in 2014. The FiT exists for plants between 1 and 20 MW, 20 and 50 MW and 50 to 100 MW. Since 2015, a net-metering system exists for projects below 1 MW, it has been updated in 2018 to make it more user-friendly. In 2018, the Government launched The Access to Clean Energy Investment Programme to install solar PV rooftop systems on all basic health units, schools and public buildings in the province. The government has published a target of 5 GW of solar power by 2022, therefore, more projects are expected to come online in the coming years.

After installing around 900 MW in 2016, the PV market in the Philippines decreased in 2017 and 2018, with the total installed capacity reaching 995 MW at the end of 2018. 887 MW were utility-scale plants while distributed PV represented only slightly more than 100 MW. At 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. However, little was installed after the government set the due date for the FiT program, thereby creating a rush of installations in 2016.

In Vietnam, the solar market still hasn't taken off, however, the government has approved more than 70 new projects, with a total capacity of over 3 000 MW that needs to begin operations before June 2019. According to EVN, the nationally owned power company, 4,46 GW of large-scale PV power plants are to be connected by the end of June 2019. The new FiT level is proposed in 2019 and it remains to be seen further growth of the utility scale market.

The government's solar target by 2020 and 2025 is to install 850 MW and 4 GW respectively. By 2030, it aims to increase it to 12 GW.

Myanmar has signed a memorandum for building several large-scale plants and about 1,5 GW of large-scale solar projects are officially in the pipeline. In Singapore, the total PV installed capacity was 203 MW at the end of 2018 with a target of 350 MW in 2020. Uzbekistan joined a World Bank Group programme beyond the African continent. The Government of Uzbekistan is looking to develop up to 1 GW of solar power and signed a mandate for a 100 MW project in the southwestern region in May 2018. In Kazakhstan, the government aims at installing 700 MW and has established a FiT programme in 2014. Several utility scale projects of 100 MW or above were in the pipeline in 2018 and are expected to come online in 2019 or in the next years. In 2018, the Electricity Authority in Nepal launched tender procedures for projects ranging from 1 MW to 5 MW across 25 sites.

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, mainly in Asia and the Americas. Europe accounted for only 9% of the global PV market with 9,5 GW in 2018. European countries had 120 GW of cumulative PV capacity by the end of 2018, 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 to reach an overall 20% share of renewable energy in the energy mix at the European level. Directive 2009/28/EC has set mandatory targets for the Member States but lets them decide about the way to achieve their binding 2020 targets. In October 2014, the European Council adopted 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, which has been upgraded to 32% in 2018 with the "Clean Energy for All Europeans" package.

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

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 rethinking 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. In this context, it is important to mention the failure of the Emission Trading Scheme (ETS), which aimed at setting 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, such as Belgium, France, Germany, Ireland, Poland and the UK introduced Capacity Remuneration Mechanisms in order to maintain uncompetitive fossil or fissile power 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. After political agreement by the Council and the European Parliament in 2018 and early 2019, EU member states have 1-2 years to transpose the new directives into national law. Collective self-consumption models are introduced with the new energy rulebook.

The EU thereby allows different consumers located in the same building, or in the same area, to jointly enter in self-consumption and to share the self-generated electricity; thereby unlocking access to self-consumption for a wide range of consumers.

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.

EUROPE / CONTINUED

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 2018 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.

Since 2005, solar PV electricity generation capacity has increased from 1,9 GW to 116 GW at the end of 2018. 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 116 GW, the EU has further lost ground in the worldwide market, representing now only 23% of the global total of 511 GW of solar PV electricity generation capacity at the end of 2018. 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 2018 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. Several retroactive changes have further decreased investment confidence, which consequently resulted in the declining PV system market in the EU. However, the market showed some signs of growth again in 2017 and 2019 perhaps due to the 2020 milestone coming closer but also due to the achievement of grid-parity in some market segments.

AUSTRIA

FINAL ELECTRICITY CONSUMPTION 2018	71	TWh
HABITANTS 2018	9	MILLION
AVERAGE YIELD	1 050	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	169	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	1 440	MW_{DC}
PV PENETRATION	2,4	%

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 169 MW installed in 2018, the market is concentrated in the distributed segment, with only 8 MW of ground-mounted installations. BIPV installations represented around 5 MW in 2018. Off-grid development amounted to less than 1 MW. Off-grid contribute in total for around 6 MW out of 1,4 GW as Austria cumulative market end of 2018.

Systems below 5 kW are incentivized through a financial incentive. Additional investment subsidy is available for BIPV installations. Above 5 kW, the Green Electricity Act provides a FiT that was reduced in 2014. The FiT is guaranteed for 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 EURct/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.

After some years of support mechanism for PV-storage by provinces since 2014, in 2018 for the first time a federal storage support was introduced for PV home storage systems. In total, 6 MEUR were available, only 11% of the applications could be granted due to the big interest of consumers. Support rate was up to 500 EUR/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.

BELGIUM

FINAL ELECTRICITY CONSUMPTION 2018	87	TWh
HABITANTS 2018	11	MILLION
AVERAGE YIELD	962	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	434	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	4 339	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 3,1 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 1,1 GW at the end of 2018. In Flanders, large rooftops and commercial applications have developed since 2009. 434 MW were installed in the country in 2018, which represents a strong increase in comparison with the 313 MW installed in 2017. Belgium now runs 4,3 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 and end in the middle of 2018. It improved in comparison with 2016 but the maximum allowed quota for installations was not reached (~8 400 out of 12 000). The Qualiwatt programme 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 - partially - the yearly net-metering system for small systems (< 5 kW). From the 1st of January 2020, every prosumer with a < 5 kW PV system will pay the grid fee for the electricity taken from the grid (as any consumer), but they will still keep a yearly net-metering advantage on the commodity part of this electricity (up to the same amount of solar electricity injected into the grid).

Larger systems benefit from a self-consumption scheme and from an additional green certificate support scheme. 2018 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 2018.

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 2018	31	TWh
HABITANTS 2018	6	MILLION
AVERAGE YIELD	900	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	91	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	911	MW_{DC}
PV PENETRATION	3,5	%

91 MW of PV systems were installed in Denmark in 2018, with 44 MW in the distributed segment, 46 MW of utility-scale plants and less than 1 MW off grid. 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 signalling. 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 2018. In total, 990 MW of PV were producing electricity in the country at the end of 2018.

EUROPE / CONTINUED

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 RE incentives are expected to start being phased-out in 2018 and to reach completion by 2022 or later. 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.

The technology neutral action round of 2018 showed electricity from PV to be competitive with that from on-shore wind and lower than off-shore wind. This auction scheme expected to last until 2030 and the emergence of commercial PPA schemes is expected to accelerate the PV market - the first indication being the 90 MW of 2018 - and for 2019 a total of 300 MW is envisaged.

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, despite its competitiveness.

FINLAND

FINAL ELECTRICITY CONSUMPTION 2018	87	TWh
HABITANTS 2018	6	MILLION
AVERAGE YIELD	875	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	53	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	134	MW_{DC}
PV PENETRATION	0,1	%

The total capacity of grid-connected PV plants is estimated at around 123 MW. However, the market in 2018 witnessed visible signs that installation rates of grid-connected rooftop PV systems is continued to grow for residential and commercial buildings with 53 MW installed. There have been no utility-scale PV plants (P >10 MW) 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 53 MW of new grid-connected PV capacity installed in 2018, the cost of all PV support measures was approximately 12 MEUR. The decision for the investment subsidy is made by Business Finland 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 considered.

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

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

FRANCE

FINAL ELECTRICITY CONSUMPTION 2018	478	TWh
HABITANTS 2018	68	MILLION
AVERAGE YIELD	1 160	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	862	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	8 961	MW_{DC}
PV PENETRATION	2,1	%

The national Multiannual Energy Plan (MEP) was published, with a 2023 target of 20,6 GW, requiring national capacity to be more than doubled over the coming 4 years. Having identified the possibility of not meeting previous, lower, MEP targets for photovoltaics, the government led a consultative process with industry actors through the year. At the end of the process several measures were announced, with the intention of accelerating the deployment of photovoltaics in France. These measures included major public and private landholders (e.g. the army, supermarket operators) making infrastructure available to third-party investors, increasing the maximum size of systems eligible in the self-consumption competitive tenders, enlarging the geographical perimeter for virtual collective self-consumption projects to better include urban development zones and eco-villages, and a dedicated call for tenders for these systems.

The year 2018 was a stable year for installers and contractors in France, with 862 MW of new capacity (884 MW in 2017). Nearly 60% of new capacity was composed of utility-scale installations, installed within the framework of competitive tenders, whilst a steady 10% of new capacity was for residential systems, nearly all in self-consumption, and a small but increasing number with battery storage - there were just under 4 000 residential storage systems installed in 2018. National cumulative photovoltaics capacity was 8,9 GW at year's end.

Mainland feed-in tariffs for systems on buildings ranged from 111,9 EUR/MWh for 100 kW systems to 185,9 EUR/MWh for small systems, and to over 200 EUR/MWh in some overseas territories. The 10-year-old building integration bonus was phased out in September.

Commercial, industrial and utility-scale projects from 100 kW to 30 MW were the object of 10 competitive tenders called in 2018, for a combined capacity of 2,6 GW. The self-consumption tenders were both significantly undersubscribed and experienced a rise in tendered prices. The year's last tender for systems on buildings over 100 kW was also undersubscribed, and tendered prices were on the rise, at an average of 84,7 EUR/MWh, up from the previous sessions 76,8 EUR/MWh. Utility sized systems continued to be the main driver, but once again the 855 MW of winning tenders in the December call asked for an average 61 EUR/MWh – a price above the previous calls. In this framework, the Energy Regulator has called for a close look at Tender specifications and has already modified conditions so that even undersubscribed, the highest bidders would automatically be eliminated. The bonus of 3 EUR/MWh was restricted to citizen investment with a lower bonus available for financing through crowdfunding platforms.

GERMANY

FINAL ELECTRICITY CONSUMPTION 2018	539	TWh
HABITANTS 2018	83	MILLION
AVERAGE YIELD	1 054	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	2 960	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	45 452	MW_{DC}
PV PENETRATION	8,9	%

With installations close to 3,0 GW in 2018, Germany was ranked sixth of the largest global PV markets. Since 2014, yearly installations are constantly increasing from 1,2 GW (2014) to 3,0 GW (2018) with an ongoing positive trend in 2019. The German PV market is a GW market since more than 10 years having installed a total cumulative capacity of 45,5 GW by the end of 2018. Given the average yield and the capacity of the PV systems installed by the end of 2018, a share of 8,9% of the electricity demand could be covered by PV, while with respect to the overall electricity production in 2018, the contribution of PV reached 7,7% 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. It must be mentioned, that the sunny summer of 2018 lead to an extraordinary high yield of 1054 kWh/kWp (2017: 960 kWh/kWp).

"Breathing" Feed-in Tariff

The EEG law (Renewable Energy Sources Act) has introduced the FiT concept already 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.

To keep the balance between system prices, FiT and market development, Germany introduced the "Breathing FiT": a method allowing the level of FiTs to decline according to the market evolution. Depending on the deviation from a defined threshold value, the reduction of the FiT will be accelerated or decelerated to regulate the market growth. During 2018, the FiT was reduced due to the growing installation numbers by approximately 5,8% (Example for small rooftop systems <10 kWp: 12,6 EURct/kWh (Jan 2018) to 11,87 EURct/kWh (Jan 2019)). This trend will continue in 2019: A reduction of at least 10,9% is already confirmed based on 1,8 GW installed in the first half of the year.

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The classic (fixed tariff) FiT is restricted to systems below 100 kWp, while for systems up to 750 kWp, a partly market dependent model was established, the so called "market integration model" (see below). All systems above 750 kWp can not benefit from the FiT models but can apply for public funding through tenders (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 who run systems larger than 10 kWp pay 40% of the surcharge for renewable electricity for their self-consumed electricity. In 2018 this surcharge amounted to 6,792 EURct for every kWh consumed from the grid (in 2019: 6,405 EURct).

A programme of incentives for storage units was active from 2013 to 2018, aiming at increasing self-consumption and developing PV with battery storage in conjunction with small PV systems (< 30 kWp). Within this framework more than 32 664 decentralized local storage systems were funded until the end of 2018 with a credit volume of 534 MEUR. During 2018, 2 155 storage systems were funded, of which 2 044 were part of a new PV system and 111 being an upgrade for existing systems.

In the first years of the programme (2013-2015), more than 50% of totally installed storage systems were funded, in 2018 the share declined to 5%. At the same it is estimated that 2018 about half of the small residential PV systems were installed with storage. Thus the programme successfully helped to stimulate the market for storage systems but will not be continued. It is estimated that 40 000 storage systems for PV have been installed during 2018 summing up to a total of around 120 000.

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 government decided to add an additional volume of 4 GW for tenders in the years 2019-2021. The average price level of the successful bids declined from 9,17 EURct/kWh in the pilot auction 2015 to 4,33 EURct/kWh in February 2018. The following tenders resulted in a small increase with average values still below 5 EURct/kWh. With increasing volume in 2019 the average of successful bids increased to 6,59 EURct/kWh in March 2019 (500 MW tender) and 5,47 EURct/kWh in June 2019 (150 MW).

The commissioning deadline for the projects is two years, the implementation rate is above 96,4%.

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.

ITALY

FINAL ELECTRICITY CONSUMPTION 2018	303	TWh
HABITANTS 2018	60	MILLION
AVERAGE YIELD	1 141	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	425	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	20 108	MW_{DC}
PV PENETRATION	7,5	%

After the booming market in 2005-2013, Italy experienced also in 2018 a stable trend with around 425 MW of new capacity installed for a total capacity of 20 108 MW.

More than 822 000 PV plants were installed at the end of the year and PV electricity production reached 22 654 TWh (a decrease of 7% compared to the previous year, due mostly to lesser irradiation conditions).

The cumulative installed capacity at the end of 2018 results in a national data of 67 kW per km2 and the national power per capita is equal to 325 W per inhabitant. The analysis of the new installation in 2018 in the different regions outlines that the best performing regions are those with a high population density.

Around 81% of plants installed in Italy at the end of 2018 are in the domestic sector, almost all under the "Scambio Sul Posto" scheme (the so-called SSP is a net-billing mechanism). With more than 9 GW, most of the total installed capacity is in the industrial sector, which plants are between 200 kW and 1 MW.

Public administration owns 20 039 PV plants for a capacity of 857 MW (4,3% of the installed capacity in Italy). As a matter of fact, around 71% of the Italian municipalities have at least one PV plant owned by the public administration.

Electricity produced by PV and self-consumed amounted to 5,1 TWh in 2018, around 23% of total PV systems production, representing a slight increase compared to 2017.

Most capacity, almost 18 GW out of 20 GW, was installed between 2005 and 2013, the subsidies period, when five decrees were approved: first Feed in Premium, after Feed in Tariff, all known as "Conto Energia". The cost of the incentive is covered by a component of the electricity tariff structure paid by all final consumers (the financial cap set by FiT law was 6,7 BEUR in terms of yearly payments).

After the end of the FiT law in 2013, tax credit (available only for small size plants up to 20 kW), together with a net-billing scheme (SSP), are the remaining measures to support PV market. Self-consumption is allowed for all PV system sizes.

SSP is a net-billing scheme for systems up to 500 kW, 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). Market prices are applied for the electricity injected into the grid as an alternative to SSP.

NETHERLANDS

FINAL ELECTRICITY CONSUMPTION 2018	111	TWh
HABITANTS 2018	17	MILLION
AVERAGE YIELD	994	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	1 511	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	4 409	MW_{DC}
PV PENETRATION	3,9	%

In spring 2018 the Dutch political parties reached a Climate Agreement which resulted in ambitious climate goals, namely 49% CO_2 reductions by 2030, compared to 1990 levels, and to be climate neutral by 2050 - and what's more natural gas exploitation in the North of the country is on its way out. Last year, the Dutch government banned gas heaters in all new homes and as a consequence the increasing electrification of the energy system will be part of the replacement of this prevailing energy source in the Netherlands. The first steps have already been taken. Over 30 local authorities, including the largest cities like Amsterdam, Rotterdam and Utrecht, have signed a 'Green Deal' for 'gas-less neighbourhoods', over a span of the next two years. Many more will follow in the coming decades.

This Climate Agreement is an agreement between a broad range of stakeholders including market parties, NGOs, research institutes, local and national governments. In order to achieve the ambitious goals in 2030 and 2050, five sector groups or "Tables" have been established namely for Industry, Agriculture and Land Use, the Built Environment, Electricity and Mobility. Each sector group has drafted plans on how to achieve 'their share' of the CO_2 emissions reduction by 2030. Solar energy can be found in most of these "tables" as a major driver if and when it can be integrated successfully and therefore the "integration" issue of solar resources will be a major focus the coming years in this densely populated country where space in general is a scarce commodity. Emerging markets are building integrated, floating, integrated of solar into the infrastructure and into the landscape. These four focus areas for solar applications are already established in the Dutch research agenda.

Besides large- scale offshore wind, solar energy is the most rapidly growing energy source across the Netherlands and installed capacity is expected to double within the next few years. In June the CBS (the national central bureau for statistics) reported 1 510 MW installed capacity over 2018 and these figures may still be corrected later this year as there is a backlog of solar parks that come in production and are in the process of certification. That brings the total accumulated amount of solar power in 2018 to 4 414 MW in the Netherlands.

A steady acceleration is observed in the yearly installed capacity that is likely to continue to around 2 GW installed a year in 2019 if limiting factors, such as lengthy planning permissions and grid congestion, can be avoided. Currently the growth of especially solar parks within the SDE plus scheme for larger systems (above 15 KW) is outpacing the speeds with which the necessary grid enforcements can be implemented. The largest solar park realised in the Netherlands of 54,5 MW is still modest by international comparison but again integration into the grid, the physical and social environment are major challenges.

The net metering scheme for smaller roof top installations is guaranteed until 2021 after which it will be phased out gradually. This category still holds the majority of the installed capacity a year in the Netherlands, but the category of ground mounted solar parks and commercial roof tops is developing faster. An increasing percentage of self-consumption would help avoid massive grid enforcements and could provide for a politically considered "reasonable" pay-back time of about 7 years.

The solar industry in the Netherlands is present along various parts of the value chain. Based upon its strong position in solar R&D and a broad industrial base in chemicals, glass and the semi-conductor industry, the Netherlands has some world-leading companies active in the international value chain. Local production of feedstock is very small if any since materials like coatings are not included here. The production of modules is relatively small, focused on niche markets and very dependent on the international developments.

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NORWAY

FINAL ELECTRICITY CONSUMPTION 2018	122	TWh
HABITANTS 2018	5	MILLION
AVERAGE YIELD	882	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	23	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	67	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 2018, the grid-connected segment dominated the market completely with 23 MW installed.

Overall, the total installed capacity reached 67 MW at the end of 2018. 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 2018.

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 are 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 they 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 2018	48	TWh
HABITANTS 2018	10	MILLION
AVERAGE YIELD	1 513	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	88	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	673	MW_{DC}
PV PENETRATION	2,1	%

The Portuguese PV market reached 88 MW in 2018, registering a small increase with respect to the previous yearly level of installations (64 MW in 2017 and 52 MW in 2016). The industrial segment was again the largest with 53 MW installed, while the other distributed grid-connected segments reached 35 MW together. 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. The total installed capacity reached about 673 MW end of 2018.

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 programme 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 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 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 2018	269	TWh
HABITANTS 2018	47	MILLION
AVERAGE YIELD	1 745	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	288	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	5 659	MW_{DC}
PV PENETRATION	3	%

Current regulatory framework for utility-scale renewables in Spain results of the 24/2013 Power Sector Act and Royal Decree 413/2014. These bills retroactively stopped the previous FiT system and introduced a scheme based on the remuneration of capacity rather than production. The system, based on government-estimated standard costs, established a reasonable profitability referenced to the Spanish national bond.

Regarding self-consumption, the 24/2013 Power Sector Act was developed by Royal Decree (RD) 900/2015 that included several administrative, technical and economic barriers that have been very restrictive for the sector. The RD charged self-generated energy of facilities above 10 kW with a 'grid backup toll' (commonly known as the sun tax) and included an additional tax for battery storage.

This set of regulations has driven the deployment of PV facilities during previous years to levels significantly below the country's potential, considering that high solar resource is available in most parts of the territory. However, this situation is about to be reversed in the upcoming years.

Aside from the auctions, PV projects are being developed obtaining financing through Power Purchase Agreements (PPAs) or just going merchant. Using information of System Operator (REE), as of June 30, 2019, 43 GW of PV have obtained the permits for connecting to the network and are awaiting construction and commissioning, and 69 GW are in the process of obtaining them.

In addition to the favourable investment trend, in 2018 there was a government change in Spain which radically changed the energy policy, setting the ecologic transition as a priority of the political agenda. The new government set out to establish an energy transition strategy by drawing the necessary legislation to comply with European environmental targets to 2030.

The electricity mix included in the NCEP also considered specific values for PV utility-scale deployment targeting 37 GW of installed power in 2030.

SWEDEN

FINAL ELECTRICITY CONSUMPTION 2018	141	TWh
HABITANTS 2018	10	MILLION
AVERAGE YIELD	950	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	159	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	426	MW_{DC}
PV PENETRATION	0,3	%

PV installations increased once again in Sweden in 2018: 158 MW were installed compared to 85 MW the year before. In recent years, the market for grid-connected PV systems has grown rapidly in Sweden. This continued in 2018 as 156 MW of the 158 MW was grid-connected systems. Of the grid-connected PV capacity, 10 MW is estimated to be centralized PV parks and 146 MW distributed PV systems for primary self-consumption. By that, the annual market of centralized PV in Sweden grew with about 294% and the distributed annual market by 82% as compared with 2017, when approximately 3 MW of centralized and 80 MW of distributed PV was installed.

The total installed capacity reached the 425 MW mark in 2018 compared to 267 MW at the end of 2017. Of this, 391 MW were distributed grid-connected systems, 20 MW were centralized ground-mounted grid-connected PV parks and 14 MW off-grid PV systems.

Swedish PV market is based on self-consumption business models, which is supplemented with a direct capital subsidy programme and a feed-in premium for the excess electricity for the smallest PV systems in the form of tax deduction.

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 programme has since been extended, support levels have changed, and more money has been allocated several times. For 2018 the budget was increased to 1 085 million SEK to meet the high demand. After the election in the autumn 2018 the parliament passed an autumn budget which decreased the annual budget for the direct capital subsidy to 436 million SEK for 2019. In the spring of 2019, the new formed government added 300 million SEK to the budget, so the total budget for 2019 is 736 million SEK. In May 2019 the government also lowered the percentage of the

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installation costs that the subsidy cover. From 30%, which was the applicable percentage in 2018, to 20%. Discussions are ongoing on how to phase out this programme in a reasonable pace that are in line with the price development.

Net-metering has been discussed and investigated in Sweden. However, instead of introducing net-metering the government introduced a sort of a feed-in premium (in the form as a tax deduction) of 0,06 EUR per kWh in 2015 for the excess electricity fed into the grid. Only PV owners with a fuse below 100 amperes are entitled to this tax deduction. 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. 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 TWh until 2020. In 2018, 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.

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 and the ongoing regulation changes that lessen the administrative procedure. However, the administrative burden and long queue in getting the investment subsidy need to be addressed properly in order for the market to uphold the fast growth in upcoming years.

SWITZERLAND

FINAL ELECTRICITY CONSUMPTION 2018	58	TWh
HABITANTS 2018	9	MILLION
AVERAGE YIELD	980	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	271	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	2 177	MW_{DC}
PV PENETRATION	3,4	%

271 MW solar installations were connected to the grid in Switzerland in 2018, an 11.9% increase compared to 2017, thus putting an end to the decrease of newly installed PV capacity seen of the last two years. This is likely a consequence of the new energy act adopted in May 2018 and the improved conditions for PV development that come with it, though the added capacity did not reach again the expected 300 MW threshold. In total, Switzerland hosted 2,17 GW of PV systems at the end of 2018. Their production corresponded to 3,38% 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 (no ground mounted PV installation in Switzerland has been installed in 2018). The total off-grid applications market stand around 5 MW with an annual market that increased this year to approximately 1 700 kW (it was only 400 kW added in 2017). In 2018, residential installations (smaller than 30 kW) represented 122 MW, the commercial segment (30-100 kW) about 38 MW and the industrial one (> 100 kW) 109 MW, which gives the ratio 46% residential / 19% commercial / 35% industrial for grid connected installed capacity (BAPV + BIPV). In 2017 this ratio was 48% residential / 11% commercial / 41% industrial, the market is shifting towards installations between 30 kW and 100kW, even though smaller installations still represent the main part of installed capacity. BIPV represented in 2018 around 38 MW out of the total 271 MW installed (which represents 14%, similar to the 13% in 2017).

About 15 550 systems have been installed in 2018, corresponding to an increase of 20% compared to 2017. The largest segment are residential installations between 4-20 kW with more than 10 000 systems installed. As in 2017, a shift towards smaller installations resulted in a decrease in the average size of a PV installation in Switzerland from 26.7 kW (in 2017) to 25 kW.

Funding for feed-in tariffs are almost finished 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 2018 were self-consumption and direct subsidies.

In 2017, a national vote on the Energy Act has increased the level of funding for renewable in Switzerland from 1,5 cCHF/kWh to 2,3 cCHF/kWh. This increase mainly support existing hydropower, but also introduced subsidies for large PV installation up to 50 MW.

Direct subsidies for larger installations have accordingly been introduced since January 2018 (around 300 CHF/kW). The waiting time to obtain those subsidies use to be around 6 years, thereby implying some uncertainties. From November 2018 onward the waiting time changed to around 2 years, which began to push the larger installation segment. Together with new regulations for collective self-consumption, these measures improved the conditions for the realization of larger PV installations. An increase of the share of installations >30 kW is expected for 2019.

Operators of PV installations that are not benefiting from the (limited) FiT scheme sell the electricity that is not consumed on site to their local Distribution System Operator (DSO). DSO are obliged to buy renewable energy injected into the grid (for system smaller than 3 MW). On the other hand, they have a large flexibility to decide the injection price, the law only mention that this price should be like the purchase price of a similar energy. In

2018, this price varies strongly from one DSO to another and lies in the range of 0,04 to 0,15 CHF/kWh. Ever for larger plant, self-consumption rate and electricity price are therefore key drivers for the profitability of PV plants in Switzerland.

OTHER COUNTRIES

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 in 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. 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 the Greek mainland 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 2 140 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 December 2018. These figures do not include the installed capacity of non-interconnected Greek islands, which - according to the Hellenic Electricity Distribution Network Operator SA - was 166 MW in March 2019. In total about 46 MW of new PV capacity was installed in 2018.

After the European Commission approved the new auction scheme, the first renewables auction in Greece was held on 2 July 2018. Since then three additional auctions were held, which resulted in an allocated PV capacity of about 700 MW. In the last tender the average PV tender tariff was 0,06278 EUR/kWh, a solar electricity price 9,37% lower than the tender's starting level of 0,06926 EUR/kWh.

In Hungary, the National Renewable Action Plan 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 in the same year.

In July 2017 the European Commission approved the new renewable support scheme (METÁR). 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 2018, Hungary connected about 410 MW of PV systems, increasing the cumulative PV power to over 750 MW by the end of the year.

In Poland, the National Renewable Action Plan foresees to reach a renewable energy share of 15,5% in the gross final energy consumption 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. So far three auctions took place in 2016, 2017 and 2018. A total of 871 MW was awarded to 964 projects. About 50% of the 416 projects awarded in the first two auctions with about 171 MW capacity were installed until the end of June 2019.

In 2018, Poland connected about 235 MW of PV systems, increasing cumulative installed capacity to 500 GW. About 80% of this capacity is represented by small and micro installations and 20% are systems larger 500 kW, which either won RES auctions or were still installed under the old green certificate system.

Between 2011 and 2018 the solar photovoltaic electricity capacity increased from less than 100 MW to 13,1 GW in the United Kingdom. In 2018, PV systems generated 12,9 TWh or 3,8 % of the UK electricity generation.

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. 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 GBP 50 (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.

In Croatia, PV systems with a capacity up to 5 MW are eligible for a FiT. According to the Croatian Energy Market Operator, 53,43 MW of PV systems were installed under this scheme at the end of May 2019. Between 1 and 2 MW additional capacity was added in 2018. In April 2019, Hrvatska Elektroprivreda announced to build four PV power plants with a combined capacity of 11,3 MW until April 2020. Until 2030 the company plans to increase its solar PV capacity to 350 MW.

Despite high solar radiation, solar PV system installation in Portugal has grown very slowly. In 2018, 88 MW of PV systems were newly installed increasing the cumulative capacity to 673 MW by the end of 2018. In the first four months of 2019 a further 58 MW were installed. Electricity from Photovoltaic system provided 1,86% of the net electricity generation in 2018.

EUROPE / CONTINUED

On 7 July 2019, a solar auction with a total capacity of 1,4 GW was held. 64 companies offered a total capacity of 10 GW. In the end 1,15 GW of capacity was awarded to 25 projects. The winning bids were between 14,76 EUR/MWh and EUR 31,16 EUR/MWh. These projects have to be realised until the end of June 2022.

After two years of rapid growth 2010 and 2011, the Slovakian market fell by almost 90 % with only 35 MW and 45 MW new installations in 2012 and 2013 and has been always been below 5 W since. The total capacity of 565 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 2018 about 260 MW of new PV capacity was installed in Russia, increasing the total capacity to around 860 MW (including ca 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 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 7 projects with 110 MW to be operational by 2021 and 2022.

Due to the fact that systems below 1 MW fall under the category of "non-licenced plants" the market started to take off. At the end of 2018, the cumulative capacity had exceeded 5,4 GWAC, most of it in the category of "non-licenced" according to the Turkish transmission operator. In May 2019 the Turkish Energy Market Regulatory Authority (EPDK) published new rules for net metering of PV systems with a capacity between 3 and 10 kWp. Also, in May 2019, the Turkish Government amended the rules for "non-licenced plants" increasing the project size up to 5 MWDC. However, only public installations used for agricultural irrigation, water treatment plants or waste treatment facilities are eligible as ground mounted projects.

In 2009, Ukraine introduced the "Green Tariff" policy, a feed-in tariff scheme for electricity generated from renewable energy sources. The scheme was modified a few times in the last years to adapt the remuneration levels. The latest change came in April 2019. For systems larger 1 MW an auction system will be introduced. Two auctions are planned each year on 1 April and 1 October.

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.

Over 700 MW of new PV power capacity was installed in 2018, thus increasing the total capacity to almost 1,4 GW (excluding the approx. 400 MW in Crimea). In the first four months of 2019, before the changes took effect more than 600 MW were installed.

MIDDLE EAST AND AFRICA

Continuing the rising development trend started in 2014 and 2015, many countries, especially in the Middle East have connected new PV power plants and more are in the pipeline. 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 2018	70	TWh
HABITANTS 2018	9	MILLION
AVERAGE YIELD	2 175	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	406	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	1 358	MW_{DC}
PV PENETRATION	4	%

Israel installed 406 MW of new PV systems in 2018, whereas between 2012 and 2017, the country installed on average about 135 MW annually. In total, close to 1,4 GW of PV systems were operational in Israel at the end of 2018. Of this capacity, around 0,5 GW comes from PV projects exceeding 5 MW, while the remaining power is represented by residential and small commercial installations up to 50 kW (320 MW), and distributed generation PV plants up to 5 MW (downsized to 5 MW) (300 MW). On top of this, there are more than 240 MW of capacity installed under the country's net metering scheme.

During 2016-2017 the Public Utility Authority (PUA) allocated a quota of 1 600 MW for PV, which led, in 2018, to the installation of 475 MW. Total RE capacity in Israel has increased accordingly to 1 636 MW, a 37% increase in total solar capacity compared with 2017, a fourfold increase in annual installations compared with the previous year, and twice the installations of the former best year (2015). Overall Israel has reached the level of about 4% of RE electricity generation in 2018. PV systems are still the most abundant RE resource in Israel, accounting for approximately 95% of installed capacity.

2018 marked a significant change in Israel's energy market with a major reform in the Israeli energy market, the publication of the 2030 objectives for the Energy market, and strong promotion for rooftop solar. Several steps were taken to simplify new construction of PV, and strong incentives were given to rooftop PV, as it is the easiest and quickest to install (in comparison to solar fields). The rooftop efforts are expected to yield approximatively 480MW in 2019.

Reform in the Electricity Market

The electricity sector in Israel is dominated by vertically integrated Israel Electric Corporation (IEC). In June 2018, the Israeli government approved a reform initiated by the Ministry of Energy, Ministry of Finance, and the PUA. The reform was designed to increase competition in the electricity generation market by reducing IEC shares in the generation segment, separate the system operator activity from the IEC, open the supply segment to competition, and strengthen IEC in the transmission and distribution segment. The reform provides great opportunities for new players in the market and is expected to have a significant impact on the electricity market in Israel.

Regulatory Framework for Rooftop Solar

In 2018, the PUA published a new rooftop regulatory framework for the next three years. The scheme included net metering, FITs for small-scale solar, and a series of tenders. The scheme regulates the installation PV on household roofs, commercial and industrial facilities, public buildings, parking lots, pergolas, water reservoirs and fishponds. Under the new framework, PV projects up to 15 kW will be eligible for net metering or apply for a 25-year FiT of 0,48 ILS ($0,137)/kWh (not indexed to inflation). Furthermore, the framework will support PV systems ranging in size from 15 kW to 100 kW, with a 25-year FiT of 0,45 ILS ($0,129)/kWh (not indexed to inflation). The framework entails a series of tenders, starting in the upcoming summer. The minimum capacity to be allocated in a single tender will be 50 MW. A participant can either sell all electricity to the grid at the winning tariff or sell the electricity to other consumers who are connected to same solar rooftop. Lastly the PUA permits construction of PV outside of the framework for self-consumption with low tariff of only 0,16 ILS ($0,045)/kWh for the surplus. This is a major change of PUA rules, as in Israel the bilateral sale of renewable electricity was not allowed prior to the introduction of these new provisions. Quota for net-metering were finished in 2018 and are not expected to be extended.

MOROCCO

FINAL ELECTRICITY CONSUMPTION 2018	28	TWh
HABITANTS 2018	34	MILLION
AVERAGE YIELD	1 722	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	NA	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	NA	MW_{DC}
PV PENETRATION	NA	%

The Moroccan market has been fully dominated by large-scale solar plants developed through public tenders. However, so far CSP has been favoured 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 amount 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.

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 2018	249	TWh
HABITANTS 2018	82	MILLION
AVERAGE YIELD	1 527	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	2 943	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	7 149	MW_{DC}
PV PENETRATION	4,2	%

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 2 943 MW in 2018.

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 their PV production are not limited in size. Cumulative grid-connected installed PV power in Turkey reached to 7 149 MW by the end of 2017. Huge increase in distribution

MIDDLE EAST AND AFRICA / CONTINUED

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 USDcents/kWh. For the tender for the Karapinar Renewable Energy Resource Area (YEKA), a consortium has been awarded by submitting the lowest bid, 6,99 USDcents/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 2018	193	TWh
HABITANTS 2018	58	MILLION
AVERAGE YIELD	1 733	kWh/kW
2018 PV ANNUAL INSTALLED CAPACITY	60	MW_{DC}
2018 PV CUMULATIVE INSTALLED CAPACITY	2 409	MW_{DC}
PV PENETRATION	2,2	%

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 and only 60 MW in 2018. At the end of 2018, the total installed capacity for utility-scale PV plants reached 2,4 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 MW. 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, especially in the African countries. However, 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. At the beginning of 2019, more than 12,4 GW was operational in the region.

In the Middle East, countries such as Saudi Arabia, Bahrain, Jordan, Oman and the United Arab Emirates have defined targets for renewable and solar energy for the coming years. Tenders are an integral part of the plans for PV development in the short or long term the region, several were organized again in 2018 and more are announced.

The Kuwait National Petroleum Company (KNPC) has launched a tender for up to 1,5 GW of solar. Dubai will install 1 GW in the coming years and more has been announced. Jordan is aiming for 1 GW of PV in 2030 and already launched several tenders. Qatar launched its second tender for 500 MW in 2018. Saudi Arabia launched a series of tenders in 2018, with an initial objective of totalling 3,3 GW. Bahrain has announced the development of 225 MW, Oman has launched several tenders, each for at least 500 MW and plans to reach 4 GW of RES capacity by 2030, Tunisia launched a tender for 500 MW, Libya 100 MW and Lebanon plans 180 MW towards 2020.Winning bids in the most recent tenders have reached extremely low levels again, down to 0,024 USD/kWh in Jordan for instance.

Despite the declining costs and the introduction of net metering policies, the region, is not yet tapping in its potential in terms of solar distributed generation.

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 which had less than 50 MW of PV capacity installed last year. Despite these uncertainties and difficulties, the country reaffirmed its ambition recently.

In Africa, besides South Africa, the fastest movers are Egypt, Morocco and Algeria which have announced plans to develop PV, at GW-scale. Reunion Island, Senegal, Kenya, Mauritania, Namibia and Ghana also already installed some capacity. As the costs are decreasing, the interest in PV is growing in other African countries. However, the market has not really taken off yet, and the higher upfront investment cost remains a barrier despite lower LCOE. 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 others. 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 (20 MW), Namibia (30 MW), Cameroon (30 MW and 25 MW projects ongoing and 125 MW tender announced with Botswana), and Kenya (where PPA were signed at a quite high price before the announcement of moving towards tenders) to name a few. In Nigeria a solar power project company launched a tender for the engineering, procurement, construction and operation of a 100 MW solar plant. 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. In this context, micro-grids and off-grid PV applications such as water pumping installations are expected to play a growing role to bring affordable power to remote areas.

MIDDLE EAST AND AFRICA / CONTINUED

TABLE 2.2: 2018 PV MARKET STATISTICS IN DETAIL

COUNTRY	2018 ANNUAL CAPACITY (MW)				2018 CUMULATIVE CAPACITY (MW)			
	GRID-CONNECTED		OFF-GRID	TOTAL	GRID-CONNECTED		OFF-GRID	TOTAL
	DECENTRALISED	CENTRALISED			DECENTRALISED	CENTRALISED		
AUSTRALIA	1 695	2 043	37	3 775	7 810	2 783	284	10 953
AUSTRIA	169	0	0	169	1 431	0	7	1 440
BELGIUM	396	40	0	435	3 565	773	0	4 338
CANADA	158	3	0	161	1 085	2 009	0	3 095
CHILE	10	587	0	597	22	2 349	0	2 371
CHINA	20 960	23 300	0	44 260	50 690	124 342	368	175 400
DENMARK	44	46	1	91	724	263	4	991
FINLAND	53	0	1	53	123	0	11	134
FRANCE	357	505	0	862	5 342	3 589	30	8 961
GERMANY	2 211	749	0	2 960	33 838	11 564	50	45 452
ISRAEL	121	285	0	406	524	834	0	1 358
ITALY	344	82	0	425	8 449	11 659	0	20 107
JAPAN	808	5 852	2	6 662	37 294	18 695	173	56 162
KOREA	470	1 795	0	2 265	1 134	6 965	0	8 099
MALAYSIA	69	408	27	503	303	519	38	860
MEXICO	298	3 319	0	3 617	570	3 507	25	4 103
MOROCCO	NA	NA	NA	NA	NA	NA	NA	NA
NETHERLANDS	625	886	0	1 511	2 307	2 107	0	4 414
NORWAY	23	0	0	23	54	0	13	67
PORTUGAL	37	51	0	88	183	346	144	673
SOUTH AFRICA	60	0	0	60	345	2 064	0	2 409
SPAIN	187	29	73	288	328	5 185	146	5 659
SWEDEN	146	10	2	158	392	20	14	426
SWITZERLAND	269	0	2	271	2 173	0	5	2 177
THAILAND	239	164	0	403	599	2 827	10	3 459
TURKEY	0	2 943	0	2 943	1	7 139	9	7 149
USA	4485	6 195	0	10 680	25 140	37 358	0	62 498
TOTAL IEA PVPS	**34 232**	**49 291**	**144**	**83 666**	**184 424**	**246 896**	**1 331**	**432 751**
NON-IEA PVPS COUNTRIES				**19 559**				**79 543**
GRID CONNECTED				**102 555**				**509 521**
ESTIMATED OFF GRID				**670**				**2 773**
TOTAL GRID + OFF GRID				**103 226**				**512 294**

SOURCE IEA PVPS & OTHERS.

three

POLICY FRAMEWORK

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

Recently, policies have evolved towards supporting the deployment of PV in various market segments, with a reduced focus on competitiveness, and an increased willingness at reducing barriers and opening new business models for PV development. Since the question of the competitiveness of PV is less pressing, a large part of new policies focused on developing distributed PV through self-consumption and further, decentralized self-consumption. In parallel, the development of utility-scale PV is now increasingly driven by tenders and similar auction schemes. This shows a growing interest from regulators and policymakers to frame the development of PV where it matters. In general, targets for PV development have increased and PV has left its niche place to be considered as a mainstream energy source.

Since the competitiveness of PV has increased, even if it is not guaranteed in all segments and locations, financial incentives might still be needed for some years in several locations. The times of excessive financial support is not gone but targeted support is still needed to overcome costs, as well as psychological or investment barriers in many countries.

Policies supporting distributed PV and self-consumption policies might be considered as non-financial incentives since they set up the regulatory environment to allow consumers to become prosumers. However, these policies require fine tuning, especially on grid costs and taxes, which in some cases could be considered as indirect financial incentives. In general, self-consumption policies as explained below simplify and adapt the regulatory framework to allow PV self-consumption to develop.

In addition to direct policies supporting PV development, other indirect policies have a tremendous effect on PV development, or on some technologies in particular. The role of policies in the near future will become increasingly essential to support a smooth PV market development.

Today, climate policies have an indirect effect but are shifting upwards the competitiveness of renewable energy sources. Some countries have indicated the willingness to significantly increase "carbon" taxes, propelling PV's competitiveness and accelerating its development.

In some countries, sustainability policies are part of a push towards a cleaner industry and in particular some technologies. In addition to GHG emissions, they focus on hazardous materials, air or land pollution and more.

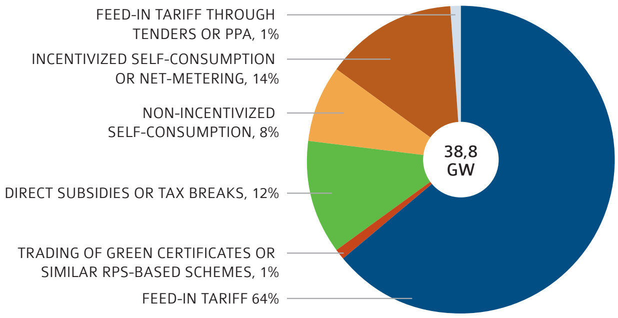
Grid codes and tariffs, even if not applicable to PV only, also frame the ecosystem in which PV develops, but adding or alleviating constraints for developers and prosumers.

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.

Finally, cross-sectoral aspects of PV development will also imply that PV will be submitted to additional regulations and policies, especially in the building and transport sector, but also in agriculture, the urban environment, industrial processes and more.

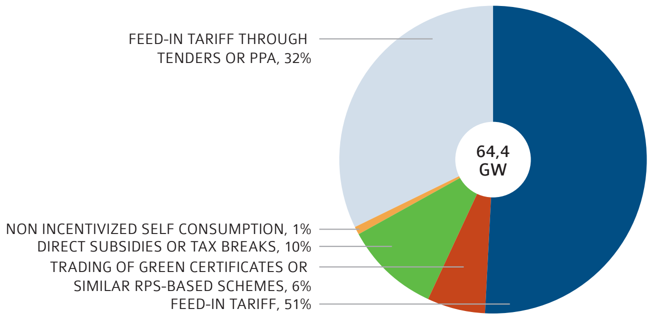
This chapter looks at the major trends in PV supporting policies until mid-2019.

FIGURE 3.1A: MAIN DRIVERS OF THE DISTRIBUTED PV MARKET IN 2018



SOURCE IEA PVPS & OTHERS.

FIGURE 3.1B: MAIN DRIVERS OF THE CENTRALIZED PV MARKET IN 2018



SOURCE IEA PVPS & OTHERS.

PV MARKET DRIVERS

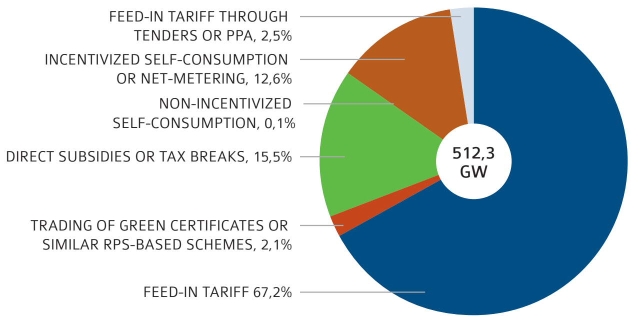
The question of market drivers is a complex one since the market is always driven by a series of regulations and incentives. In these figures, the focus is put on the major driver for each macro-segment (distributed or centralized), while other drivers are playing a key role. This should be regarded as a general indication, and the dynamics from one year to another are telling more than the annual snapshot.

Figure 3.1a and 3.1b taken together shows that in 2018, 5% of the volume of the market became independent of support schemes or adequate regulatory frameworks: this implies installations not financially supported and realized through outside of tenders or similar schemes. This is a significant improvement compared to previous years. However, that improvement is visible for distributed applications, while utility-scale PV remains limited. However, the trend is clear, and Spain and Chile have started to host PV plants selling their production on electricity markets.

Around 32% of utility-scale plants or 20% (compared to 7% in 2018) of all installations were realized through tenders: this is a significant increase compared to previous years and the sign that super-competitive prices have seen their share of the market increasing: at 20%, this is not a major concern yet for the industry. However, most countries are transitioning to tenders to grant PPAs and the numbers are expected to grow significantly in 2019 with massive installations expected and started in 2018 in Vietnam, the United Arab Emirates, Egypt and Spain; in addition to the markets in which such tenders were already delivering such as Germany, Chile, Brazil.

Globally, about 76% of the PV installations are receiving a predefined tariff for part or all their production: in addition to PPA and FiT through tenders, 56% of all installations are still driven by Feed-in Tariffs. Despite that the share of the market driven by FiT hasn't diminished significantly through the years, there is global trend towards lower tariffs. This diminishing trend of the FiT is in line with the price decrease of the technology. Pure FiT outside of tenders represented 51% in centralised grid connected PV systems and 64% in the distributed PV market.

FIGURE 3.2: HISTORICAL MARKET INCENTIVES AND ENABLERS



SOURCE IEA PVPS & OTHERS.

With around 10%, direct subsidies are the third most represented form of support for PV, most of the time they don't cover the whole installation cost.

Incentivised self-consumption, including net-billing and net-metering represented 14% of the distributed PV market, a rather stable level compared to historical installations. 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. Although net-metering is being abolished in historical markets, countries such as Thailand and Ecuador introduced net-metering for residential PV owners recently. Net-metering remains an easy way to activate the distributed PV market but requires shifting to self-consumption later.

Green certificates and similar schemes based on RPS represented around 4% of the market, a decreasing number. Green certificate trade still exists in countries such as Belgium, Norway, Romania and Sweden. Similar schemes based on RPS exist in Australia and Korea for instance.

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 INCLUDING PPA

The concept of FiT 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 injecting into the grid rather than for local consumption. Amongst the IEA PVPS members, 16 countries had a FiT implemented in 2018 (Australia, Austria, Canada, China, Denmark, Finland, France, Germany, Israel, Japan, the Netherlands, Portugal, Sweden, Thailand, Switzerland, Turkey and the United States). The attractiveness of FiT has been slightly reduced but they still drive a large part of the PV market as shown in Figures 3.1, FiT represent more than 56% of the 2018 PV market. The announcement by China that the FiT would be replaced by a tendering process is expected to confirm the awaited decline of unconditional tariffs for PV electricity. But so far it still represents a major driver of PV installations.

National or Local

Depending on the country specifics, FiT can be defined at the national level (China, Japan, Germany, etc.) and at the regional level (Australia, Canada, India) with some regions opting for it and others not, or with different characteristics.

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

Automatic or Ad Hoc Adjustment

The market can grow out of control if there is an imbalance between the level off the tariffs and effective cost of PV systems, especially when the budget available for the FiT payments is not limited. Indeed, most market booms in countries with unlimited FiT schemes were caused by the unforeseen steep price decrease of PV systems, while the level of the FiT was not adapted fast enough. This situation caused the market to grow out of control, mainly in European countries, which were the early adopters of support measures. The market booms occurred in countries such as Spain in 2008, Czech Republic in 2010, Italy in 2011, Belgium in 2012 and to a certain extent in China in 2015, 2016 and 2017, and to a lesser extend to other countries.

With the "corridor" principle effective since 2013 in Germany, the level of the FiT follows closely market installation levels. Indeed, 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.

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 and, China for instance. FiT remains a very simple instrument to develop PV, but it needs to be fine-tuned on a regular basis to ensure a stable market development.

Tendering and Auctioning

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 20% of all PV installations in 2018 (and this should increase again in the coming years), it is conceivable that they don't represent the average PV price in all cases but showcases for super-competitive developers.

Tenders

Tenders allow controlling installations but haven't yet shown their full potential. For the time being, they are mostly used to frame PV development. For regulators, this implies defining a maximum capacity and proposing the cheapest suitable plants to develop. However, it could be further and be part of a larger, long-term, roadmap on power capacity development. By planning smartly, together with transmission grid operators, tenders could allow to develop specific capacities for defined technologies, optimize the grid and plan smartly the energy transition. Although, this would become more complex for rooftop PV.

THE SUPPORT SCHEMES / CONTINUED

Tenders have gained success in the entire world over the last years and Europe aligned with this trend while several countries adopted or reintroduced tenders. Several countries such as **France**, **Germany**, **Greece**, **Poland**, **Portugal** and **Spain** introduced or reintroduced tenders for different market segments, 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 rather using it for utility-scale plants.

In the Middle East and North Africa, tenders were issued in **Bahrain**, **Egypt**, **Israel**, **Jordan**, **Morocco** and the **UAE**. In the rest of the world, many others have joined the list of countries using calls for tenders to grant PPAs for PV plants. In Latin America, **Argentina**, **Brazil**, **Guatemala**, **Mexico** and **Peru**, just to mention the most visible, have implemented such tenders. In Asia, **Nepal** and **Sri Lanka** also started to launch tenders, while in Africa in addition to **Egypt** and **Morocco**, **Nigeria**, **Senegal**, **Tunisia** and **Malawi** can be cited amongst the newcomers.

Brazil, **India**, **Jordan**, **Mexico** and **Saudi Arabia** were the most competitive markets in recent years, the organized tenders attracted bids around or even below 20 USD/MWh in the sunniest places. However, **Portugal** probably holds the new record low price as the lowest bid came in at 14,76 EUR/MWh (16,44 USD/MWh) during the summer 2019 (even if this tender seems below the reachable costs level in 2019). Bids below 40 EUR/MWh occurred for the first time in **Germany's** auction for large-scale solar. **Armenia** and **Senegal** went below the same threshold as well (respectively 46,00 and 48,87/MWh in USD).

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. 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. Tenders can be technology specific (Greece, Japan, 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. Some countries such as France and Germany are experimenting with first mixed auctions (solar and wind) in parallel with some technology specific tenders.

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

TABLE 3.1: LOWEST WINNING BIDS IN PV TENDERS FOR UTILITY SCALE PV SYSTEM BETWEEN Q1 2018 AND Q3 2019

REGION	COUNTRY/STATE	USD/MWh
LATIN AMERICA	BRAZIL	17,52
EUROPE	PORTUGAL	18,17
AFRICA	TUNISIA	24,40
MIDDLE EAST	JORDAN	24,80
ASIA	INDIA	35,00
LATIN AMERICA	BRAZIL	35,58
EUROPE	GERMANY	48,63
AFRICA	SENEGAL	48,87

EURO exchange rate adapted in september 2019.
1 EURO = 1.228 USD

SOURCE IEA PVPS & OTHERS.

Additional Constraints

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, Japan and more recently in France.

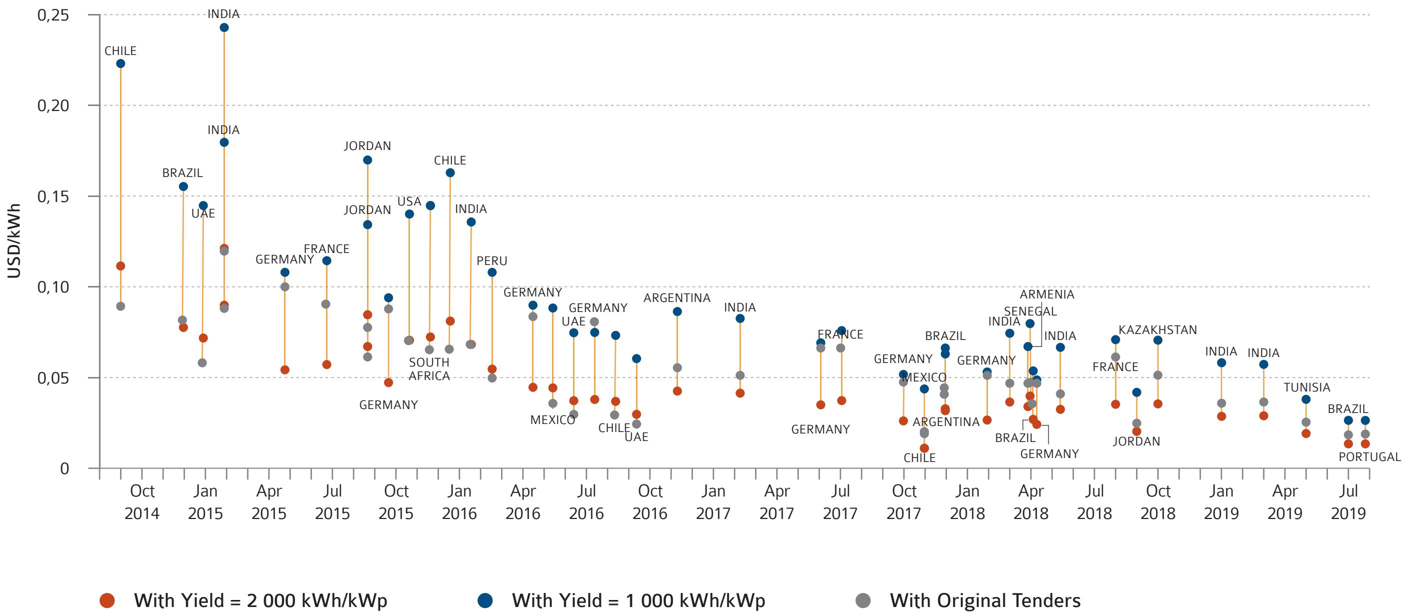
China, through its "Pilot" or "Frontrunner" program favours high-efficiency technologies. In general, the level of the tariff depends on the segment, but it can also evolve during the lifetime of the plant to follow some key indicators. FiT increasing over time for existing plants have been seen but 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.

Support for Manufacturing

Increasingly, countries try to introduce local manufacturing content requirements in either FiT schemes or tendering schemes. 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. In several countries, a local content parameter has been discussed and acts as an additional primary or secondary key in the grant decision. This is the case in Morocco for instance, but this has been proposed in numerous countries so far.

FIGURE 3.3: NORMALIZED LCOE FOR SOLAR PV BASED ON RECENT PPA PRICES DURING 2014 - Q3 2019



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. A so-called 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.

CORPORATE 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 competitive since they rely on PPAs with private companies rather than official FiT schemes.

Spain is probably leading the PPA market, if not worldwide, at least in Europe. Over the last years more and more bilateral PPAs were signed between producers and electricity retailers; the producer-consumer PPA are still rare.

The USA and Australia are also markets were PPAs are gaining market shares. In California, many PPAs, sometimes with record low prices, were approved over the last years. PPAs by definition imply sourcing of solar electricity without being co-located with the production, a solution favoured more and more by large companies willing to decrease their GHG emissions.

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, Norway and Romania, 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. In Belgium, all three regions use 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. Romania uses a quota system, too, which however experienced a drop in the value of the green

THE SUPPORT SCHEMES / CONTINUED

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.

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 upfront investment in order to incentivize PV. Direct subsidies were implemented in countries such as Austria, Australia, Sweden, Japan, and Italy; 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. Off-grid applications can use such financing schemes in an easier way, than for instance FiT that are less adapted to off-grid PV development.

Tax credits have been used in a large variety of countries, ranging from Canada, the USA, Belgium, Switzerland, France, Japan, 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. Direct subsidies amounted to 10% of the global PV market in 2018.

“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 incentivize the development of PV or any other renewable source because of the low carbon price that came out of the system. A Market Stability Reserve (MSR) has been introduced to reduce the surplus of emission allowances in the carbon market and to improve the EU ETS's resilience to future shocks. The EU will further reinforce this mechanism: between 2019 and 2023, the amount of allowances put in the reserve will double to 24% of the allowances in circulation and other measured could be introduced in the coming years.

Outside of Europe, Japan was amongst the first countries to adopt a carbon pricing in 2012. More recently, a national carbon-pricing plan took effect in 2018 in Canada. Although the tax is federal, the price varies between the Provinces and territories. China launched its own cap-and-trade carbon program in December 2017, the first phase of the market only covers power generation. A carbon tax also came into effect in South-Africa in June 2019.

The share of global GHG emissions covered by carbon prices initiatives is now around 20%, with China and the EU as main contributors.

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.

SELF-CONSUMPTION AND NET-METERING

With around 37% of distributed PV installations in 2018, 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 analyse and compare self-consumption policies. This “Review of PV Self-Consumption Policies” proposes a methodology to understand, analyse 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.

Local and Collective Self-consumption

Self-consumption implies revenues coming from savings on the electricity bill, while the excess electricity can eventually benefit from a FiT system. These savings can be decreased if grid taxes or levies are to be paid on the self-consumed electricity. Fixed or capacity-based grid tariffs can also have a detrimental effect on the revenues for the prosumers. These last years, countries such as Germany, Spain or Belgium introduced taxes on solar PV production for prosumers. These taxes where in most cases fought in court and finally retrieved.

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 10-15 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 injected on the grid electricity is not remunerated;

- Excess electricity gets the electricity market price, with or without a bonus;
- A FiT remunerates the excess electricity 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.

A net-metering system allows such compensation to occur during a longer period, ranging from one month to several years, sometimes with the ability to transfer the surplus of consumption or production to the next month(s). In Belgium, the system exists for PV installations below 10 kW but might disappear after 2020. In the USA, net-metering policies differ from state to state, consequently, the payoff time varies greatly. Several emerging PV countries have implemented net-metering schemes in recent years (Israel, Jordan, UAE (Dubai) and Chile).

Collective, Decentralized or "Virtual" Self-Consumption

The next concept arising concerns the extension of self-consumption models to distant production and consumption sites: While self-consumption could be understood as the compensation of production and consumption locally, it offers innovative alternatives once it becomes collective or decentralized. Collective self-consumption allows to share electricity between several users, in general behind the meter. Self-consumption in collective buildings or sites allows one or more production units to feed their electricity to several consumers, using a predefined split key. The typical case concerns a multi-apartment building, with one single PV plant feeding several or all consumers in the building. Such systems start to develop in France and the Netherlands, which propose adequate policy frameworks. This is referred to as "collective" self-consumption.

Decentralized (or "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 than prosumers at regional or national level. Such policies are tested in some countries (Austria, Netherlands, France, Mexico, Switzerland, etc.). Some utilities even launched pilot projects before the regulations were officially published (as in Austria or Switzerland). In this case, innovative products are already mixing with PV installations, PV investment and virtual storage. This evolution will be scrutinized in the coming years since it might open new market segments for solar PV.

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 believed decentralized self-consumption can ease the integration of PV into the energy transformation, support the development of smarter buildings and accelerate the transition to electric vehicles.

The opportunities opened by such concepts are wide-ranging. For instance, this could allow charging an electric vehicle in the office with PV electricity produced at home, or sharing the PV electricity in all public buildings in a small town between them depending on the consumption, or installing a utility-scale plant in the field nearby a village to power it. Options are numerous and imply fair remuneration of the grid to be competitive for all. Using PV electricity in a decentralized location implies the use of the public grid, distribution or even transmission and would require putting a fair price on such use. With PV becoming competitive, such ideas emerge and could develop massively under the right regulations.

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 electricity 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.

COST OF SUPPORT SCHEMES

The cost of these incentives can be supported through taxpayer's 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 who re-invoices these 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.

COST OF SUPPORT SCHEMES / CONTINUED

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 decided in 2016 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.

France: The CSPE surcharge part for PV amounts to 22,5 EUR/MWh with partial or whole exonerations possible for certain sectors. For residential consumers in France, support for photovoltaics represents approximately 5% the cost of kWh consumption.

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 2019, the EEG surcharge will decrease to 6,4 EURcts/kWh. End users must pay the value added tax (19%) on this surcharge so that the costs imposed on private households increases to 7,6 EURcts/kWh for all renewable energies. The contribution of PV is considered as small compared to wind in the last year.

Japan: The surcharge to promote renewable energy power generation for a 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 199,4 TWh as of the end of September 2018, approaching 7,9 TJPY in total.

Malaysia: The FiT scheme is supported by the Renewable Energy (RE) fund contributed by electricity consumers of TNB, SESB and NUR Distribution Sdn Bhd. Consumers with electricity consumption of more than 300 kWh per month are obliged to contribute additional charge of 1,6% of their electricity bill to the RE fund. The RE fund is managed by SEDA to support the renewable energy developers who invest in PV, small hydro, biomass, and biogas resources to generate electricity. The NEM and LSS schemes are supported by a passthrough mechanism to the consumer tariffs.

Spain: The renewable support is financed through the electricity tariff as a regulated charge that all electricity consumers pay. In 2018 the total amount awarded for PV support was 2,446 MEUR according to the Spanish regulator, the CNMC.

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 size (utility scale or distributed).

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 tend 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. However, 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 financing and operations, as well as reducing the uncertainty on the long term for the prosumer, it is possible that such services will develop in the near future, along with the necessary developments which will push up the distributed PV.

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.

It is interesting to note that many transmission system operators are increasing the penetration of PV in their scenarios and try to assess the impact of such developments. In 2019, the French TSO has issued a clear assessment of the positive effect of massive PV development on generation adequacy during the morning peak while it concluded that the balancing costs for several dozen of GW of PV in the French network would have negligible costs while high-voltage grid reinforcements costs would amount to significantly less than 1 EURcts per kWh in France. Such scenarios and calculations have been done by many TSOs and show how important PV development starts to become.

Grid Codes

Grid codes have a little-known effect on PV development. By submitting PV applications to stricter grid codes and regulations, connecting PV systems to the grid becomes more complex. Without being a driver of PV development, grid codes start to become a more complex prerequisite for some PV applications. The increased need to provide ancillary services to the grid, including frequency response for instance, and curtailment, changes the nature of the connection for the PV system and can increase prices or reduce revenues. This influences the competitiveness of PV solutions. Grid codes have been reviewed in the European Union in the last years for instance and will lead to additional constraints for PV systems. In 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.

Grid Costs and Taxes

Grid costs are another essential element, which deals with PV competitiveness, especially for distributed PV applications under self-consumption. Since the competitiveness of the solution depends on the ability to reduce the electricity bill of the consumer, the grid costs might affect tremendously the outcome. In particular, several countries discuss the shift of grid costs from an energy-based structure towards a capacity-based structure: this would affect significantly the profitability of distributed PV plants if all grid costs would have to be paid, even with large shares of the energy produced on site. This comes from an explainable fear from grid operators to see their revenues and therefore their capacity to invest and maintain the grid, being reduced significantly if prosumers or semi-independent energy communities would become the new normal. However, the current penetration levels of distributed PV remain rather acceptable and leave time to find the right solutions. The example of decentralized self-consumption indicates how important it will be for the grids to know their real costs and invoice prosumers with a fair tariff depending on the real use of the grids. The changing electricity landscape with the fast development of electric mobility in several countries, the development of distributed storage and the expected electrification of heating, would deserve a long-term analysis, rather than a punishment policy for PV prosumers.

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.

SUSTAINABLE BUILDING REQUIREMENTS & BIPV

With more than 35% of PV installations on rooftops, 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) but 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 show that PV is chosen in more than 85% of the new buildings. In Denmark, the national building code has integrated PV 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 favour decentralized

SUSTAINABLE BUILDING REQUIREMENTS & BIPV / CONTINUED

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.

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

BIPV support policies have been quite popular a few years ago, especially in Italy and France where they led to massive installations, with almost 5 GW of cumulative installations in these two countries. Since then, their level has been massively reduced and few countries apply now BIPV policies with dedicated incentives. Such policies supported the use of conventional PV modules for simplified BIPV installations, which led to abuses and more constraints in the BIPV policies. Since then, the development of more constraining BAPV policies imposes in some cases higher constraints to BIPV development. An example is the limit at 100 kW for non-tendered applications in France which would impose de facto to BIPV to compete with BAPV and lead in all cases to the choice of BAPV for systems above 100 kW. Since BIPV targets building surfaces, limits are defined by the surface, rather than electricity consumption choices only. This will definitively limit BIPV development in such cases in the coming years. In addition, the end of financial incentives reduces the attractiveness of BIPV which didn't benefit as BAPV did of the tremendous price decrease linked to its massive development.

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 2018 few countries provided specific subsidies for storage system development.

In Germany, soft loans and capital grant covering up to 25% of the eligible solar PV panel were offered between 2016 and 2018. A similar programme was available between 2012 and 2015 offering 30% rebate per project. solar storage systems below 30 kilowatts received subsidies that could cover up to 30 percent of their battery system's cost. In Sweden the government has introduced a direct capital subsidy for energy storage owned by private households. Canada has established several innovation funds that have given rise to solar projects with electricity storage. projects all over across the country. In the USA, several states, including California, provide rebates for qualifying distributed energy systems.

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. In 2018, China installed around 729 MW of new battery-storage capacity. China is a key global manufacturer of Li-Ion batteries and its electric vehicles markets is the largest in the world.

France organized several solar tenders with storage between 2011 and 2017 in its islands: Corsica (15 MW), Reunion and Mayotte (17,5 MW), Guadeloupe, French Guiana and Martinique, Saint Barthelemy and Saint Martin (17,5 MW).

In Italy, fiscal incentives for residential PV were extended to storage. Some regions support the adoption of storage systems coupled with residential and commercial PV with some additional rebates.

Japan is as well trying to increase the numbers of projects to install storage batteries but with still limited subsidies. In the past years storage batteries for residential applications were part of a subsidy program to accelerate the development of net zero energy houses.

Some consider that storage development for PV electricity will be massively realized through electric vehicles connected to the grid during a large part of the day and therefore, will be able to store and deliver energy to consumers at a larger scale than simple batteries. This vehicle-to-grid or V2G concepts are being explored and tested in several countries, from the Netherlands to Switzerland, Japan, among others.

TABLE 3.2: 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	used		used	used	used		used	used		used	
AUSTRIA	used		used		used			used	used	used	used
BELGIUM		used		used	used		used	used			used
CANADA	used	used	used		used	used		used			used
CHILE				used	used		used				
CHINA			used	used	used				used		
DENMARK			used		used			used			
FINLAND	used	used	started	used	used			used			used
FRANCE	used		used	used	used	used		used			used
GERMANY			used	used	used	started					used
ISRAEL			used	used	used						used
ITALY	used	used		used	used	used		used		used	
JAPAN	used	used	used		used		used	used			
KOREA	used	used			used		used				
MALAYSIA			cancelled	used	used						
MEXICO				used	used						
MOROCCO	NA	NA	NA	NA	NA (used)	NA	NA	NA	NA	NA	NA
NETHERLANDS	used		used	used	used	used	used	used			
NORWAY	used			used	used		used				used
PORTUGAL			used		used		used	used			used
SPAIN					used	used			used		used
SWEDEN	used	used	used	used	used	used		used		used	used
THAILAND			used		used						
SWITZERLAND	used	used	used	used	used	used	used	used	used	used	used
TURKEY			used	used	used						
USA	used	used	used	used	used	used	used				used

- started: This support scheme started in 2018
- used: This support scheme has been used in 2018
- cancelled: This support scheme has been cancelled in 2018

SOURCE IEA PVPS & OTHERS.

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 2018, including project development as well as operation and maintenance (O&M) is also briefly presented. This chapter is intended to provide an 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 in 2018 stayed almost at the same levels as those of 2017. However, the production of polysilicon, ingots, wafers, PV cells and modules increased at a pace higher than the growth of the installed capacity. China remains the world's largest producer and consumer of PV cells and modules, therefore, the decision of the Chinese government to control the development of PV projects at the end of May 2018 significantly impacted the global PV supply and demand. This has led to price reduction across the PV value chain from polysilicon to PV module. As a result, the price competitions have intensified, and the reorganization of the PV industry has continued.

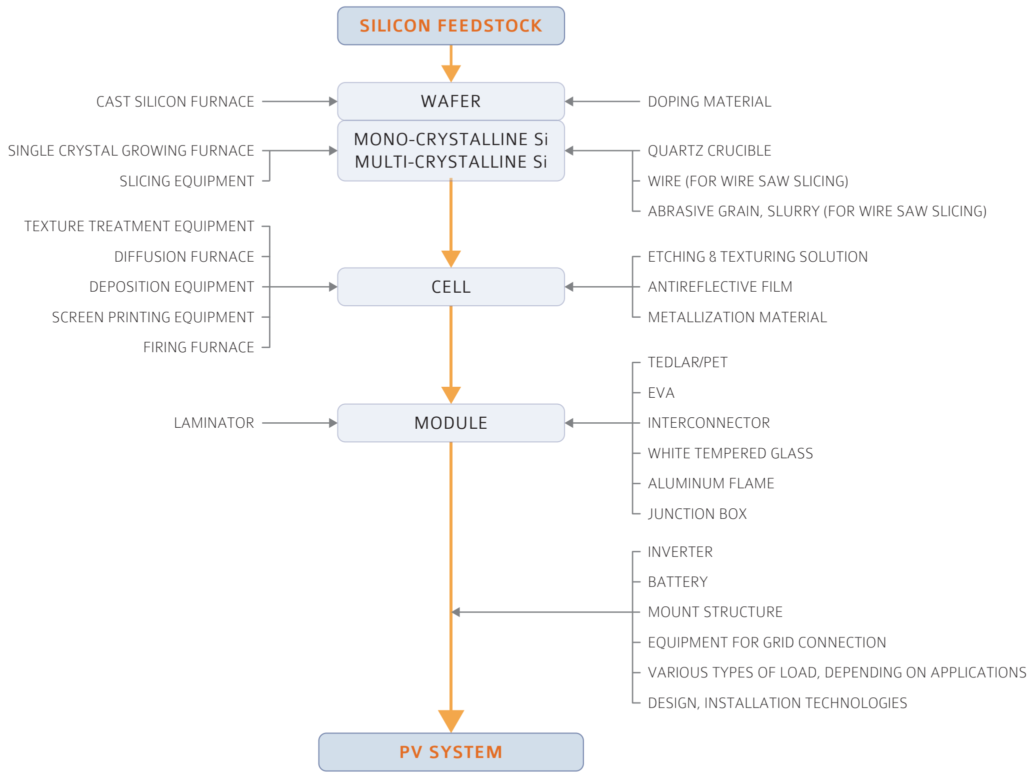
Expecting the future growth of the global PV market, major PV manufacturers have continued expanding their production capacities. Continued trade conflicts are impacting the strategies on production bases by PV manufacturers. In the USA, which have implemented safeguard measures, manufacturers announced expansion of PV module production capacity. Also, capital investment has been concentrated in Thailand and Vietnam, which are not subject to the safeguard measures. Despite the ongoing market developments, concern of oversupply remains.

Throughout 2018, the price of PV modules (spot price of multi-crystalline silicon (mc-Si) PV module) gradually decreased, from 31 USD cents/W in the beginning of the year to 22 USD cents/W at the end of the year. This has led to the reduction of investment cost to install PV systems. Furthermore, manufacturers are working on increasing output capacity of PV modules. Production volume of single crystalline silicon (sc-Si) PV modules significantly increased in 2018 reaching 46,5% of market share compared to 31% in 2017.

THE UPSTREAM PV SECTOR

This section reviews some trends of value chain of crystalline silicon and thin-film PV technologies. While a PV system consists of various manufacturing processes and materials, this section focuses on the key trends of polysilicon, ingot/wafer/cells and PV modules (crystalline silicon and thin-film PV) as well as inverters.

FIGURE 4.1: PV SYSTEM VALUE CHAIN (EXAMPLE OF CRYSTALLINE SILICON PV TECHNOLOGY)



SOURCE IEA PVPS & OTHERS.

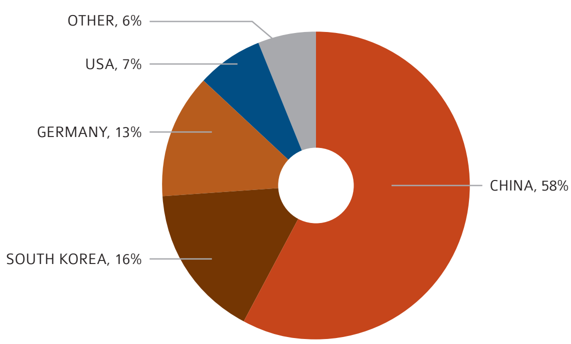
POLYSILICON PRODUCTION

Wafer-based crystalline silicon technology remains dominant for producing PV cells. In that respect, this section focuses on the wafer-based production pathway and provides background information on the upstream part of the PV value chain.

The global polysilicon production (including semiconductor grade polysilicon) in 2018 was 480 000 tons. Polysilicon production for solar cells increased to approx. 448 000 tons in 2018, up by 6 000 tons from 442 000 tons in 2017. Polysilicon production for semiconductors increased from approx. 32 000 tons in 2017 to approx. 34 000 tons in 2018. The production volume of polysilicon for solar cells accounted for about 93% of total production of polysilicon in 2018. As shown Figure 4.2, China accounts for 58% of polysilicon production for solar cells, ranking first in the world. South Korea ranked second with 16% of global share following by Germany and USA.

The global polysilicon production capacity continuously increased along with the increasing demand for polysilicon for solar cells. At the end of 2018, the global polysilicon production capacity was 643 000 tons/year, an increase of about 100 000 tons/year from the end of 2017 (170 000 tons/year was newly added, whereas about 70 000 tons/year stopped operation, making a net growth of

FIGURE 4.2: SHARE OF PV POLYSILICON PRODUCTION IN 2018



SOURCE IEA PVPS, RTS CORPORATION.

THE UPSTREAM PV SECTOR / CONTINUED

100 000 tons/year). Total production capacity of seven major Tier 1[3] manufacturers in 2018 amounted to about 333 000 tons/year, up from 300 000 tons/year in 2017, accounting for about 52% of the global production capacity. In 2019, it is expected that the global production capacity of polysilicon will increase by about 120 000 tons/year to reach over 700 000 tons/year. Meanwhile, considering the production plans of manufacturers, the production volume in 2019 is estimated to be about 500 000 tons. It is assumed that oversupply will not be resolved on a short-term basis. On the other hand, demand for high quality wafers for high efficiency solar cells is increasing and it is possible that there will be shortages for the supply of high purity polysilicon.

With the improvement of efficiency of PV cells and modules and efforts to reduce use of materials such as thinning of wafers, the amount of polysilicon used for 1 W of wafer (consumption unit of polysilicon) has been decreasing year after year. In 2017, it is estimated that, on average, 4,9 g/W (at least about 4,0 g/W) of polysilicon were used for a solar cell, and it decreased to 4,0 g/W in 2018. Compared to 7,2 g/W in 2009, the consumption unit of polysilicon decreased at a pace of 6,3%/year.

The spot price of polysilicon varies depending on the market developments, and it dropped significantly in 2018. At the beginning of 2018, it was 18 USD/kg, and it kept decreasing throughout the year. The spot price drastically dropped, particularly after the announcement of the policy change by the Chinese government at the end of May 2018. It dropped sharply from 15 USD/kg to the level of 10 USD/kg in two months, to reach 9,5 USD/kg at the end of December 2018. One should not focus solely on the fluctuations of the spot price of polysilicon, since a large number of companies are procuring polysilicon based on long-term supply agreements. Regarding long-term supply agreements signed between 2006 and 2010 when there was a shortage of polysilicon, some PV cell/module manufacturers amended the contents of the supply agreements or reported losses in 2018.

Most of major polysilicon manufacturers adopt the Siemens process, which is a manufacturing process of polysilicon for the semiconductor industry. Some manufacturers adopt the FBR (fluidized bed reactor) process to manufacture granular polysilicon. Production efficiency has improved, and energy consumption of the reduction process was improved from 50 kWh/kg in 2017 to 49 kWh/kg in 2018. Reduction processes utilizing advanced technologies are reported to have decreased energy consumption to 40 kWh/kg. The energy consumption of the whole process decreased from 73 kWh/kg to 71 kWh/kg. The reduction of electricity consumption under the reduction process has been achieved by the efforts including the following: 1) development and commercialization of large-scale reduction furnace; 2) improvement of inner wall materials of the furnace; 3) replacement of conventional silicon tube with silicon core; 4) adjustment of gas mix. Electricity consumption will probably be reduced further by the optimization of the process and economy of scale, which is assumed to contribute to the reduction of polysilicon price.

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. Some companies reported their efforts on production of granular silicon due to its cost advantage.

Shaanxi Non-Ferrous Tian Hong REC Silicon Materials (Yulin JV), a joint venture established by REC Silicon (Norway) and Shaanxi Non-Ferrous Tian Hong New Energy (SNF) (China), started development of granular silicon with the FBR process in the first quarter of 2018. The company has the production capacities of 18 000 tons/year for FBR-based granular polysilicon, 1 000 tons/year for Siemens-based polysilicon, and 500 tons/year for silane gas. In 2018, the company manufactured 5 400 tons of FBR-based polysilicon, 100 tons of Siemens-base (semiconductor grade) polysilicon. Asia Silicon (China) announced that it successfully developed granular polysilicon in June 2018 by the process of direct decomposition of chlorosilane. According to Asia Silicon, it is possible to manufacture granular polysilicon with 10 kWh/kg or lower electricity consumption, compared to about 40 kWh/kg for manufacturing Siemens-based polysilicon. In 2017, GCL-Poly Energy (China) acquired the FBR technology from SunEdison (USA) for manufacturing polysilicon.

As in the previous years, the major solar-grade polysilicon producing countries among IEA PVPS countries were China, Germany, South Korea, USA, Malaysia and Norway in 2018. China continued to be the largest producer and consumer of polysilicon in the world.

Affected by China's policy change announced on May 31, 2018 to control development of PV projects, the number of polysilicon manufacturers in China decreased to 18 by the end of 2018, from 24 at the beginning of the year. China produced 259 000 tons of polysilicon in 2018, which accounted for about 57,8% of the total global polysilicon production, up by 1,8% from 2017. The production capacity of polysilicon in China in 2018 increased to 388 000 tons/year, an increase of 112 000 tons/year from 276 000 tons/year in 2017. The consumption of polysilicon for solar cells in China was 371 000 tons in 2018, of which China imported about 137 000 tons, down by 13,8% from 2017. China's imports of polysilicon decreased for the first time in the last ten years. Most of the imports were from South Korea, Germany and Malaysia.

The largest polysilicon manufacturer was GCL-Poly Energy (Jiangsu Zhongneng Polysilicon Technology Development), which produced 61 785 tons in 2018. GCL-Poly Energy has remained to be the world's largest polysilicon manufacturer. The company's polysilicon factory in the Xinjian Uygur Autonomous Region, China (60 000 tons/year production capacity) started the Phase 1 operation with 48 000 tons/year production capacity, which has made the company's total production capacity of 118 000 tons/year as of the end of June 2019. China's second largest polysilicon manufacturer is Xinte Energy (TBEA group), which produced 34 000 tons of polysilicon in 2018. In the first half of

3 Bloomberg New Energy Finance (BNEF) defines Tier 1 module manufacturers as those which have provided own-brand, own-manufacture products to six different projects, which have been financed non-recourse by six different (non-development) banks, in the past two years.

2019, it completed a 36 000 tons/year new factory, which will increase its production capacity to 70 000 tons/year as of the end of 2019. Ranked third is Daqo New Energy, who produced 23 351 tons of polysilicon. Daqo plans to expand its polysilicon production capacity to 70 000 tons/year by the end of 2020. In 2019, the company is expected to add about 147 000 tons/year of polysilicon production capacity in China and over 90% of the production capacity could be used for manufacturing high quality polysilicon for sc-Si wafers.

Germany has a domestic polysilicon production capacity of over 60 000 tons/year. Wacker Chemie possesses production capacity of 60 000 tons/year and 80 000 tons/year in total when adding the production capacity of a factory in Tennessee, 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. Wacker shipped about 60 000 tons of polysilicon in 2018, a drop of 10 000 tons compared to the shipment of about 70 000 tons in 2017. This is attributed to the impacts of the PV market developments in China. In order to avoid anti-dumping duties in China, at its US factory, the company produces solar-grade polysilicon targeting countries other than China and semiconductor-grade polysilicon for China. The company produced about 58 000 tons of polysilicon in 2018, and ranked second in the global polysilicon manufacturing, same as 2017.

South Korea reported 82 000 tons/year of polysilicon production capacity in 2018. The country's largest polysilicon manufacturer OCI acquired the Malaysian polysilicon factory (13 800 tons/year) from Tokuyama (Japan) in May 2017 and increased the factory's production capacity to 20 000 tons/year. As of the end of 2018, its total effective production capacity reached 72 000 tons/year globally (52 000 tons/year in South Korea). It is estimated that the company produced some 5 000 tons of polysilicon in 2018. The company announced to focus on producing high purity polysilicon corresponding to increase in demand of p type sc-Si wafers. Other Korean polysilicon manufacturers are Hanwha Chemical, Hankook Silicon and SMP (joint venture of LOTTE Fine Chemical and GCL-Poly Energy).

In the USA, major polysilicon manufacturers are Hemlock Semiconductor, REC Silicon and Wacker Chemie. In 2018, the USA had a 90 000 tons/year of polysilicon production capacity including the Tennessee Factory of Wacker Chemie. However, the polysilicon production in the USA is on a decreasing trend due to the 57% anti-dumping duties imposed on the US made polysilicon by China. Accordingly, in May 2019, REC Silicon announced that it would temporarily stop production of FBR-based polysilicon at its Moses Lake Factory in Washington, USA.

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 reportedly building a manufacturing factory in Iceland. Elkem Solar in Norway is estimated to have produced approx. 6 500 tons of polysilicon in 2018.

INGOT & WAFER

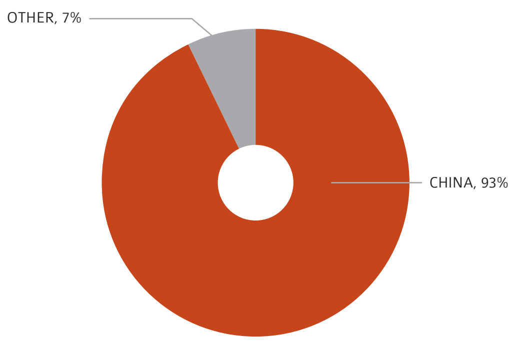
o produce single-crystalline silicon (sc-Si) ingots (also known as mono-crystalline) or multi-crystalline silicon (mc-Si) ingots, the basic input material consists of highly purified polysilicon. The ingots need to be cut into bricks or blocks and then sawn into thin wafers. Conventional silicon ingots are of two types: Single-crystalline and multi-crystalline. The first type, although with different specifications depending on 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 manufacturers of wafers. In addition to major ingot/wafer manufacturers, some PV cell/module manufacturers also partly manufacture silicon ingots and wafers for their in-house uses. Due to the cost pressure, some of these major PV module manufacturers that established vertically integrated manufacturing are shifting to procuring wafers from specialized manufacturers because of cost and quality advantages.

In 2018, it is estimated that about 115 GW of c-Si wafers were produced. It was an increase of some 8% compared to 2017 with 106 GW. The production capacity of wafer as of 2018 is estimated to be about 156 GW/year, a 25% increase compared to 2017 with 125 GW/year. As for wafers, major manufacturers announced to continue enhancing their production capacities. By the end of 2019, global production capacity may exceed 165 GW/year.

China has a strong presence in the wafer production as well. According to a report by Silicon Branch of China Nonferrous Metals Industry Association, the wafer production in China in 2018 was 95 GW, accounting for about 93% of the global production, as shown in Figure 4.3. GCL-Poly Energy was the largest wafer manufacturer both domestically and globally in 2018 following 2017, with production capacity of 30 GW/year and produced 24,2 GW of wafers. The second place was held by LONGi Green Energy Technology (China), that produced 364 000 wafers (about 19 GW) with the production capacity of 28 GW/year. Zhonghuan Semiconductor ranked third and produced 300 000 wafers (about 15,6 GW) with the production capacity of 25 GW/year.

FIGURE 4.3: SHARE OF PV WAFER PRODUCTION IN 2018



SOURCE IEA PVPS, RTS CORPORATION.

THE UPSTREAM PV SECTOR / CONTINUED

As for other IEA PVPS member countries, production capacities in South 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 owns the production capacity of about 1 GW/year.

In 2018, major Chinese PV manufacturers such as JinkoSolar, JA Solar and Trina Solar continued expanding their facilities for inhouse production of wafers. Meanwhile, PV Crystalox Solar (UK) withdrew from the wafer manufacturing business. Hanwha Q CELLS (Korea) also withdrew from the ingot and wafer business and decided to focus its investment on kerfless wafer technology. In China as well, companies such as Daqo New Energy and TBEA Sunoasis withdrew from the silicon wafer manufacturing business. From Japan, Ferrotec shifted its PV-related manufacturing business in China to the semiconductor sector, decided to concentrate on OEM production of wafers and withdrew from the sales of wafers on its own. Due to the oversupply, concentration of the market is expected to continue which could lead to a problematic oligopoly.

The spot price of c-Si wafer further decreased due to the impacts of China's policy change at the end of May 2018, price reduction possibility following the price reduction of polysilicon, cost reduction by introducing diamond wire saws, as well as strategic price reduction by major manufacturers. At the beginning of 2018, the price of mc-Si wafer (156 mm x 156 mm) and sc-Si wafer (same size) was 0,62 USD/wafer and 0,69 USD/wafer, respectively. In the first half of the year, the prices sharply decreased to 0,32 USD/wafer and 0,43 USD/wafer, respectively. Then the prices stayed low until the end of the year, almost at half of those at the beginning of the year. In December 2018, the prices slightly increased due partly to the dollar's depreciation. Although the demand is recovering, the price levels have remained at the same level as, or lower than the production cost. As for mc-Si wafers (156 mm x 156 mm), supply and demand are getting balanced, after the manufacturers adjusted their production over several months. Since October 2018, the price has stabilized at 0,27 USD/wafer. The price of sc-Si wafer (156 mmx 156 mm) slightly increased due to the demand for Top Runner projects in China, which was 0,38 USD/wafer at the end of 2018.

In 2018, the shares of sc-Si wafer and mc-Si wafer were 46% and 54%, respectively. The share of sc-Si wafer increased. From the technology perspective, in 2018, introduction of new manufacturing technologies to realize cost reduction and improve quality advanced in China. For mc-Si wafers, more manufacturers adopted diamond wire saw technology. The largest manufacturer GCL-Poly Energy adopted this technology on full scale in the first half of 2018 and largely reduced its production cost. As for sc-Si wafers, mass production of Continuous Czochralski (CCz) technology progressed by such manufacturers as GCL and LONGi. The CCz technology makes it possible to improve production efficiency and reduce electricity consumption, thus reducing costs. GT Advanced Technologies (USA), which developed a CCz-based sc-Si ingot manufacturing device, signed a technology license agreement on the CCz-based device with Jingyuntong Technology, a Chinese equipment manufacturer who owns a 5 GW/year c-Si ingot factory in December 2018. In 2019 onwards, it is expected that the China-made sc-Si products will gain more competitiveness due to the start of mass production of CCz technology.

Manufacturers also reported the changes in the wafer size. For sc-Si wafers, the conventional size of 6 inch (156 mm x 156 mm) has been increased to 156,75 mm x 156,75 mm, and to 158,75mm x 158,75 mm, which is currently the mainstream size. The size of mc-Si wafers has also been increased. According to the report released by the China Photovoltaic Industry Association (CPIA) in July 2019, the 158,75 mm x 158,75mm size is becoming the mainstream.

Start-up companies in the USA and Europe are developing a kerfless manufacturing process to manufacture wafers without using conventional ingot growth nor wire-sawing processes. 1366 Technologies (USA) announced in February 2019 that the company will establish a mass production factory in Cyberjaya, Malaysia, to manufacture wafers by applying direct wafer technology, which directly processes wafers from molten polysilicon, in partnership with Hanwha Q CELLS (Korea) and Hanwha Q CELLS Malaysia (Malaysia). 1366 technologies (USA) announced that it achieved 20,3% of conversion efficiency with a 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 a solar cell using Direct Gas to Wafer technology by Crystal Solar (USA). NexWafe (Germany) raised funds to establish and start operation of pilot production lines of c-Si wafers with epitaxial process.

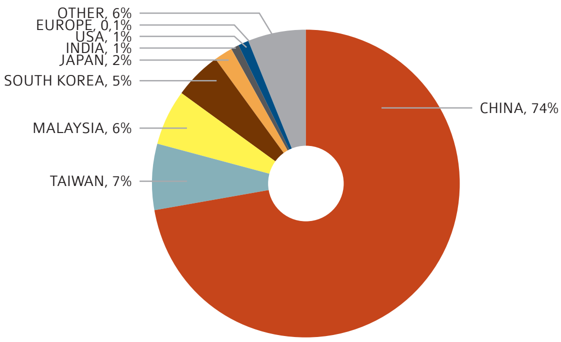
SOLAR CELL AND MODULE PRODUCTION

Global solar cell (c-Si and thin-film solar cell) production in 2018 is estimated to be around 116 GW, an 8,5% increase year on year. Same as the previous year, China reported the world's largest production of solar cells. In China, 85 GW of solar cells were produced in 2018, an 18% increase from the previous year (72 GW in 2017). China has been expanding its production capacity, and its solar cell production capacity was about 128 GW/year in 2018.

As shown in Figure 4.4, China's solar cell production volume accounts for 74% of the global total. The global solar cell production capacity reached 172 GW/year, due particularly to the enhancement of production capacity in China.

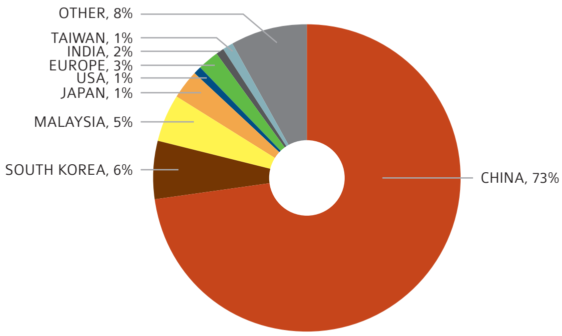
Major IEA PVPS countries other than China that reported production of solar cells are Malaysia, South Korea, Japan, USA and Thailand. Malaysia has approx. 9 GW/year of solar cell production capacity and produced nearly 7 GW of solar cells (c-Si and CdTe thin-film). In Malaysia, major PV manufacturers

FIGURE 4.4: SHARE OF PV CELLS PRODUCTION IN 2018



SOURCE IEA PVPS, RTS CORPORATION.

FIGURE 4.5: SHARE OF PV MODULE PRODUCTION IN 2018



SOURCE IEA PVPS, RTS CORPORATION.

including JinkoSolar (China), LONGi Green Energy Technology (China), Hanwha Q CELLS (Korea), JA Solar (China), SunPower (USA), First Solar (USA) and Panasonic (Japan) have factories. In South Korea, about 6 GW of solar cells were produced. In the USA, solar cell production is mainly conducted by First Solar with CdTe thin-film PV production. Major non-IEA PVPS countries manufacturing solar cells are Taiwan, Philippines, Singapore, India, and Vietnam. However, production capacity of Taiwan, which ranks second in production volume following China, is about 12 GW/year level, which indicates that China's presence is further increasing both in terms of production capacity and production volume. Thailand and Vietnam are not subject to the safeguard tariffs by the USA and the production capacities are increasing in these countries. As of 2018, Thailand and Vietnam have the solar cell production capacity of 2,6 GW/year and over 5 GW/year, respectively.

As for c-Si solar cells, demand for high efficiency solar cells has continued increasing, and in 2018, the share of sc-Si solar cell increased again, as it did in 2017. Thanks to China's Top Runner Program which requires high conversion efficiency and output capacity, demand for sc-Si PV products has been on the rise. Consequently, the share of mc-Si solar cells decreased from about 68% in 2017 to 54% in 2018. To respond to the demand for high output PV modules, major manufacturers are shifting their production lines to manufacture PERC solar cells, achieving 22% or higher conversion efficiency with mass-produced products. The production capacity of PERC solar cells is assumed to have reached about 67 GW/year as of the end of 2018.

Major solar cell manufacturers are renewing the conversion efficiency records of PERC solar cells one after another. In May 2019, LONGi Green Energy Technology (China) reported achievement of 24,06% conversion efficiency on a sc-Si PERC solar cell.

Since PERC solar cells have the structure to easily generate power on both sides, they are increasingly introduced to bifacial PV modules. Major PV module manufactures have continued making investment to improve conversion efficiencies, through such efforts as improvement of passivation process for PERC or PERT structures, thinning of electrode, adoption of four or more busbars (four busbars are the standard, and five/ six-busbar products are also on sale), as well as adoption of multi-busbar wiring or wiring without busbars.

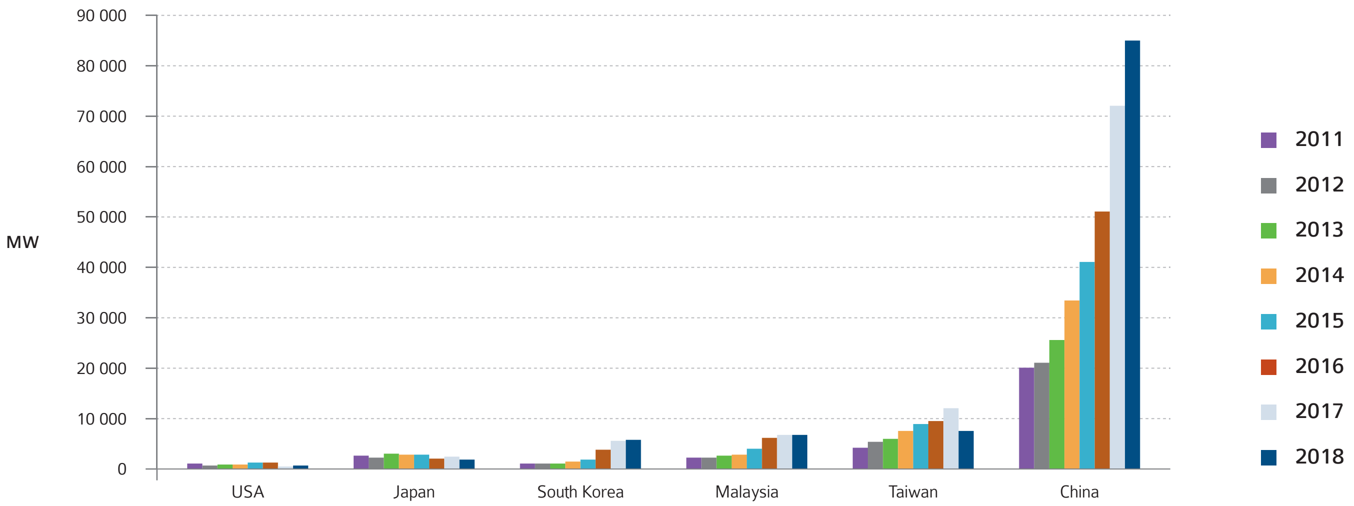
Efforts on high efficiency solar cells with the so-called post-PERC technology have also started, and enhancement of production capacity of heterojunction (HJT) solar cells is advancing, mainly in China. It is often the case that thin-film silicon PV manufacturers enter the HJT PV production. In 2018, 3SUN (Italy), a PV module manufacturing subsidiary of Enel Green Power (EGP)(Italy) started manufacturing bifacial PV modules with c-Si and amorphous silicon (a-Si) heterojunction technology at its Catania Factory in Italy. Also, as a post-PERC structure, activities on TOPCon (Tunnel Oxide Passivated Contact) technology have also progressed. In May 2019, Trina Solar (China) announced that it achieved the world's highest 24,58% conversion efficiency on the surface of a bifacial n type sc-Si i-TOPCon solar cell using a large-sized wafer (244,62 cm2). In June 2019, Trina announced that it established a mass production framework of bifacial n type c-Si i-TOPCon PV modules. On these technologies, R&D activities are also gaining momentum, aiming to improve conversion efficiency further.

Global PV module production (c-Si PV module and thin-film PV module) is estimated to be about 116 GW in 2018.

As shown in Figure 4.5 and Figure 4.6, China has remained to be the largest producer of PV modules and PV cells in the world in 2018, following 2017. China produced 84 GW of PV modules in 2018, accounting for 72% of total global PV module production. As of the end of 2018, China has the PV module production capacity of 130 GW/year.

THE UPSTREAM PV SECTOR / CONTINUED

FIGURE 4.6: EVOLUTION OF THE PV INDUSTRY IN SELECTED COUNTRIES - PV CELL PRODUCTION (MW)



SOURCE IEA PVPS, RTS CORPORATION.

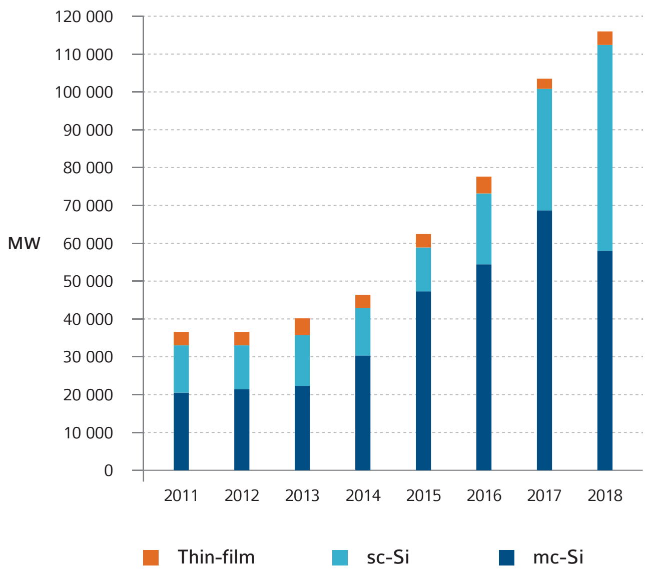
Following China, the second largest PV module producing country is South Korea that produced about 8 GW. Malaysia ranked third with about 6 GW of production. Other major IEA PVPS countries owning PV module production capacities are Japan, Germany and USA. Australia, Austria, Belgium, Canada, Mexico, Denmark, France, Italy, Finland, Sweden, Thailand, Turkey and South Africa also possess PV module production capacity.

Among non-IEA PVPS members, major countries producing PV modules are Singapore, Taiwan, Vietnam, India and Poland. Production bases have been established in Russia, Algeria, Brazil, Morocco, Ghana, Saudi Arabia, Indonesia and so on. As well as solar cells, production capacity of PV modules is increasing in Vietnam due to the impacts of trade conflicts. It was reported that Vietnam had PV module production capacity of 7 GW/year as of the end of 2018. In the USA, PV module production capacity is expected to increase due to the imposition of safeguard tariffs. Chinese and Korean companies such as JinkoSolar, Hanwha Q CELLS and LG Solar plan to start operation of total approx. 2,7 GW/year PV module manufacturing facilities in the first quarter of 2019.

India has the effective PV module production capacity of 3 GW/year. The Indian government conducts tenders for PV projects including establishment of manufacturing facilities, in order to encourage domestic industries. A similar tender was conducted in Turkey as well. In addition to the requests for lowering transportation costs, there are some countries such as France and South Korea where PV module carbon footprints are included in the requirements for support measures. It is assumed that more production bases will be established in the areas adjacent to the demand.

Figure 4.7 shows PV module production per technology in IEA PVPS countries. C-Si PV modules continues to secure an overwhelmingly large share. Among c-Si PV modules, the share of sc-Si PV modules is increasing following the rising demand for higher performance products, as mentioned above. 112 GW of c-Si PV modules were produced in 2018, accounting for 97% of all the PV module technologies, similar level to 2017, of which mc-Si PV modules had the largest volume and share of 58 GW and 50%, respectively. As for sc-Si PV modules, thanks to the increased

FIGURE 4.7: PV MODULE PRODUCTION PER TECHNOLOGY IN IEA PVPS COUNTRIES IN 2018 (MW)



SOURCE IEA PVPS, RTS CORPORATION.

TABLE 4.1: GLOBAL TOP FIVE MANUFACTURERS IN TERMS OF PV CELL/MODULE PRODUCTION AND SHIPMENT VOLUME (2018)

RANK	SOLAR CELL PRODUCTION (GW)		PV MODULE PRODUCTION (GW)		PV MODULE SHIPMENT (GW)	
1	Hanwha Q CELLS	7,4	JinkoSolar	8,6	JinkoSolar	11,4
2	JA Solar	7,0	JA Solar	8,5	JA Solar	8,5
3	Tongwei Solar	6,5	Canadian Solar	8,0	Trina Solar	7,5
4	JinkoSolar	5,8	Hanwha Q CELLS	7,7	Canadian Solar	6,8
5	Canadian Solar	5,7	LONGi Green Energy Technology	7,5	LONGi Green Energy Technology	6,6

NOTE: PRODUCTION VOLUMES ARE MANUFACTURERS OWN PRODUCTION, WHEREAS SHIPMENT VOLUMES INCLUDE COMMISSIONED PRODUCTION AND OEM PROCUREMENT.

SOURCE RTS CORPORATION (WITH SOME ESTIMATES).

supply of wafers by major sc-Si wafer manufacturers, price reduction as well as China's market trend seeking for higher efficiency under the Top Runner Program, etc., 54 GW of sc-Si PV modules were produced, accounting for 47%, up from 31% in 2017. The share of thin-film PV modules stayed at 3%.

Table 4.1 shows the global top five manufacturers in terms of PV cell/module production and shipment volume. All of them are c-Si PV manufacturers. In terms of solar cells, Hanwha Q CELLS of Korea ranked first for the fourth consecutive year with the production of 7,4 GW in 2018, almost the same volume as the previous year. Tongwei Solar of China, who focuses on solar cell production, ranked third in solar cell production. JinkoSolar produced 8,6 GW of PV modules in 2018 and has remained to be the world's largest PV module producer and supplier for the third consecutive year since 2016. In terms of PV module shipment, JinkoSolar ranked first for the third consecutive year with 11,4 GW shipment in 2018, although it includes commissioned production and OEM procurement. LONGi Green Energy Technology (China) ranked among the top five manufacturers for the first time with the shipment of 6,6 GW.

In the area of c-Si PV, reflecting the improvement of conversion efficiency of solar cells, the output capacity 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. Half-cut solar cells are made by cutting the conventional solar cells into half. As the electrical resistance within the solar cell is reduced, drop of output due to the generation of resistance heat will be curbed and reduction of conversion efficiency under high temperature in the summer can be suppressed as well, which is said to lead to increase in total power generation volume. In 2018, mass production of PV modules using half-cut solar cells has advanced further. Some forecast that in 2019, about two-thirds of newly installed PV module manufacturing lines will adopt the half-cut solar cell technology. Commercialization of PV modules with other technologies has started, including shingled PV module technology (overlapping the edges of solar cells without ribbons) and seamless soldering technology. With these technologies, output capacity of PV modules is increasing as well. Commercialization of other technologies have also progressed, including bifacial PV modules with PERC solar cells on both sides of the module, PV modules for 1,500 V connection, as well as lightweight c-Si PV modules using chemical tempered glass or polymer. As for c-Si PV modules, modules for building integrated PV (BIPV) systems have been proposed, such as modules with coating of the surface glass and coloured films.

Approx. 3,54 GW of thin-film PV modules were produced in 2018. Thin-film PV modules were mainly produced in Malaysia, USA, Japan, Germany and Italy as they were in the previous year. First Solar of the USA remained to be the world's largest thin-film PV module manufacturer. First Solar owns factories in the USA, Malaysia and Vietnam, and it produced 2,8 GW of CdTe thin-film PV modules in 2018. The company has been working on enlarging the size of PV modules and updated some manufacturing lines. With the larger-area PV modules, it realized 400 W PV modules.

Next to CdTe thin-film technology, a total of 0,8 GW of CIGS PV modules were produced in 2018 in Japan, Germany, USA, etc. New production bases are being established in China, and production of CIGS and CdTe thin-film PV modules has been reported. Hanergy started production of flexible CIGS thin-film PV modules in Hubei Province, China using technology developed by a US company MiaSole. China National Building Materials (CNBM) started operation of a CIGS thin-film PV module factory in Sichuan Province in China. The company is also manufacturing CdTe thin-film PV modules. In China, there are some other companies manufacturing thin-film PV modules. In many of the IEA PVPS member countries, R&D and commercialization efforts on CIGS thin-film PV modules toward improvement of conversion efficiency and throughput as well as enlargement of module size have been continuously reported. As for thin-film PV modules, proposals have been made on those with flexible substrates which can be installed on curved surfaces, light transmitting PV modules, roof tile-integrated PV modules for BIPV systems, and so on.

THE UPSTREAM PV SECTOR / CONTINUED

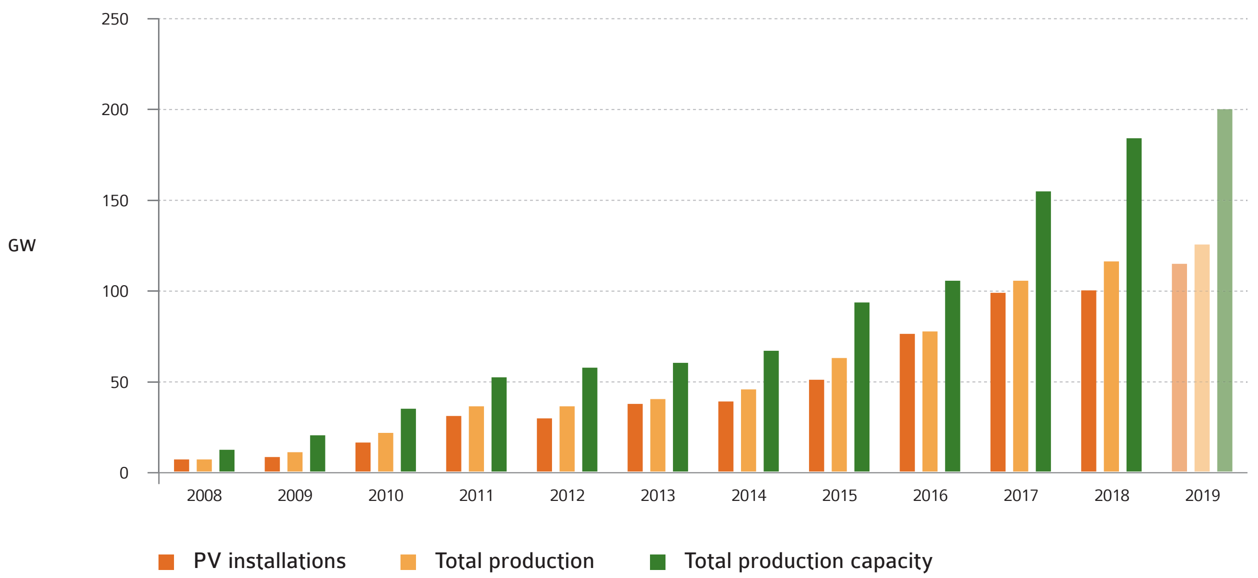
Average spot price of PV modules in the beginning of 2018 was 31 USD cents/W and gradually decreased to 22 USD cents/W by the end of the year. This price decline is the result of the widening gap between supply and demand in June 2018 onwards due to the policy announced by the Chinese government at the end of May 2018 to control development of PV projects. Prices were reduced across the PV value chain, to which the price reduction of polysilicon particularly contributed. This situation has continued giving a negative impact on the profit structure of major PV module manufacturers. Under such circumstances, integration of manufacturers has been accelerated

Figure 4.8 shows the trends of global yearly PV installation, PV module production and production capacity. Although the PV installed capacity in 2018 was slightly higher than 2017, the gap between supply and demand widened due to continued enhancement of production capacity by major manufacturers. By summing up national production capacities, the global PV production capacity is estimated to have reached 184 GW/year in 2018, up from 155 GW/year in 2017. Since this figure include the capacities of aged facilities and idle facilities that are not competitive, the effective production capacity is assumed to be at the level of approx. 160 GW/year. Improvement of conversion efficiency is assumed to contribute to the increase in production capacity. Following 2017, the largest increase of production capacity was reported by China in 2018. According to the China Photovoltaic Industry Association (CPIA), China's domestic PV module production capacity increased by about 25 GW/year, from 105 GW/year in 2017 to 130 GW/year in 2018. Reflecting the increase in PV installed capacity, the operating ratio decreased from 68% in 2017 to 63%.

Furthermore, high efficiency multi-junction PV cells/modules have been produced, mainly using III-V materials. They are mainly used for satellite PV and concentrating PV (CPV) systems. Installation of high efficiency multi-junction PV on vehicles has been studied under the stages of R&D and demonstration. Germany, USA, France, Japan and Spain are continuously conducting R&D activities on high efficiency multi-junction PV cells/modules.

Following the rapid improvement of conversion efficiency in a short time, efforts on mass production of perovskite PV cells/modules have been reported. For instance, GCL Nano Science (China) under GCL Group (China), started working on the development of a 100 MW/year mass production line in the beginning of 2019, aiming to start mass production of perovskite PV modules in 2020. Saule Technologies (Poland) aims to start mass production of flexible perovskite solar cells by 2021. Also, efforts on mass production of perovskite/c-Si solar cells were reported. Oxford PV (UK) made announcements on financing partnership with equipment manufacturer, aiming to start production of a 200 MW/year mass production line by 2020.

FIGURE 4.8: YEARLY PV INSTALLATION, PV PRODUCTION AND PRODUCTION CAPACITY 2008 - 2019 (GW)



SOURCE IEA PVPS, RTS CORPORATION.

TABLE 4.2: EVOLUTION OF ACTUAL MODULE PRODUCTION AND PRODUCTION CAPACITIES (MW)

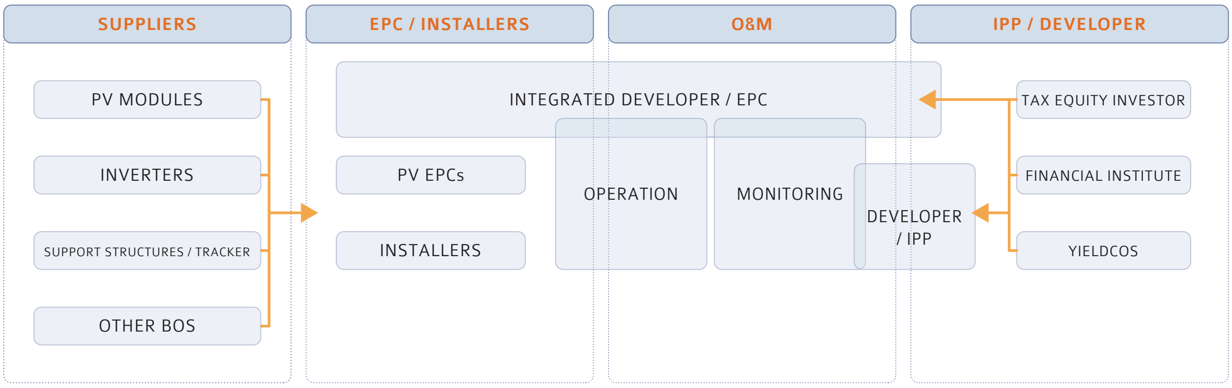
	ACTUAL PRODUCTION			PRODUCTION CAPACITIES			
YEAR	IEA PVPS COUNTRIES	OTHER COUNTRIES	TOTAL	IEA PVPS COUNTRIES	OTHER COUNTRIES	TOTAL	UTILIZATION RATE
1993	52		52	80		80	65%
1994	0		0	0		0	0%
1995	56		56	100		100	56%
1996	0		0	0		0	0%
1997	100		100	200		200	50%
1998	126		126	250		250	50%
1999	169		169	350		350	48%
2000	238		238	400		400	60%
2001	319		319	525		525	61%
2002	482		482	750		750	64%
2003	667		667	950		950	70%
2004	1 160		1 160	1 600		1 600	73%
2005	1 532		1 532	2 500		2 500	61%
2006	2 068		2 068	2 900		2 900	71%
2007	3 778	200	3 978	7 200	500	7 700	52%
2008	6 600	450	7 050	11 700	1 000	12 700	56%
2009	10 511	750	11 261	18 300	2 000	20 300	55%
2010	19 700	1 700	21 400	31 500	3 300	34 800	61%
2011	34 000	2 600	36 600	48 000	4 000	52 000	70%
2012	33 787	2 700	36 487	53 000	5 000	58 000	63%
2013	37 399	2 470	39 868,5	55 394	5 100	60 494	66%
2014	43 799	2 166	45 964,9	61 993	5 266	67 259	68%
2015	58 304	4 360	62 664	87 574	6 100	93 674	67%
2016	73 864	4 196	78 060	97 960	6 900	104 860	74%
2017	97 942	7 200	105 142	144 643	10 250	154 893	68%
2018	106 270	9 703	115 973	165 939	17 905	183 844	63%

NOTE: ALTHOUGH CHINA JOINED IEA PVPS IN 2010, DATA ON CHINA'S PRODUCTION VOLUME AND PRODUCTION CAPACITIES IN 2006 ONWARDS ARE INCLUDED IN THE STATISTICS.

SOURCE IEA PVPS & OTHERS.

THE DOWNSTREAM SECTOR

FIGURE 4.9: OVERVIEW OF DOWNSTREAM SECTOR (UTILITY PV APPLICATION)



SOURCE IEA PVPS & OTHERS.

In the PV industry, an overview of the downstream sector can be described as in Figure 4.9 (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 (FIT) 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-players companies and general construction companies offering services for installing PV systems. Integrated PV developers sometimes conduct EPC services by themselves. Some companies develop PV power 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. Under the FIT program and the tender scheme, the majority of IPPs supply electricity to electric utilities. However, in case the electricity market is liberalized, and it is systematically possible, there are some cases where PV electricity is sold to private enterprises which procure electricity generated by renewable energy sources. These cases are called Corporate PPA. Also, following the reduction of generation cost, some cases were reported, where IPPs trade PV electricity on the electricity trading market.

Companies doing business in the downstream sector have various origins: subsidiaries of electric utilities, 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 business deployment and are active in business deployment in emerging markets such as Africa, the Middle East and Latin America. The number of project 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 sector.

Global major oil companies are also shifting to the renewable energy business. Royal Dutch Shell (Netherlands) disclosed its intention to invest 1 to 2 Billion USD/year in PV and wind sectors until 2020. The company acquired a 49% stake in Cleantech Solar, a Singaporean developer of commercial PV projects, and made investment in sonnen, a German storage battery manufacturer. From UK, BP has entered the PV business through its subsidiary Lightsource BP.

Asian electric utilities are also active in the renewable energy business. Malaysian national electric power company, Tenaga Nasional developed utility-scale PV projects in Malaysia and participated in a tender held in the Middle East. KEPCO, a South Korean national electric power company is conducting PV projects in Japan, Mongolia, USA, etc. The company participated in tenders held in Ethiopia and Armenia in the form of a consortium with private enterprises. Furthermore, in 2018, it announced to invest in Solar Philippines, a major PV company in the Philippines.

It should be also noted that several vertically integrated companies are present in the downstream sector. These companies produce PV modules or polysilicon, develop PV projects and provide EPC and O&M services. Thin-film PV module manufacturer First Solar, and c-Si PV module manufacturers such as JinkoSolar, Canadian Solar and Hanwha Q CELLS are also active in the downstream sector. Notable polysilicon manufacturers investing in the international downstream business are GCL-Poly Energy and OCI.

Companies engaged in PV project development are also active in the field of storage batteries. In Australia and the USA (states of Hawaii and California), development of utility-scale PV projects with electricity storage facilities is advancing. In South Korea, under the RPS scheme, an increasing number of PV in combination with storage projects are being developed, supported by the policy measure to issue Renewable Energy Certificates (REC) with a multiplier. From Japan, it was reported that storage batteries were installed at a utility-scale PV power plant in Hokkaido Prefecture, in response to the request from an electric utility.

The downstream sector for grid connected distributed PV is different of the one for grid centralized PV. Distributed PV systems for residential, commercial and industrial applications are owned generally by the building owners or third-party companies. In some countries, especially in the USA, the third-party ownership (TPO) business model is quite active. The companies using the TPO business model provide PV systems to property owners and sign an agreement to supply PV electricity usually 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.

Some companies also provide leasing solutions in the USA and Europe.

In the markets where PV systems have already been widely installed such as the US states of California and Hawaii, as well as Australia, demand for storage batteries for PV systems is on the rise, and an increasing number of suppliers of distributed PV systems are entering the storage battery business.

Services to install off-grid PV systems in non-electrified areas in Africa and other nations are also active. The small-scale off-grid PV business is active, through divided payment of handling charge and usage fee called pay-as-you-go (PAYG) scheme, as well as rental with purchase option. Azuri Technologies (UK), BBOXX (UK) and SolarHOME (Singapore), etc. are representative examples of such cases. Some of these companies also 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 BOS components are accounting for an increasing portion of the system cost as the PV module price is falling. Accordingly, the production of BOS products has become an important sector of the overall PV industry.

The inverter technology has become the 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. Since the new grid codes require the active contribution of PV inverters to grid management and grid protection, new inverters are now being developed with sophisticated control and interactive communications features. With these functions, the PV power plants can actively support the grid management, 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, USA, Canada, 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 market segments where the cost reduction pressure is strong. In such markets, leading players with global supply chains are taking the share of regional players.

It is estimated that Chinese inverter manufacturers supplied 65,7 GW of inverters in 2018, slightly decreased from 67 GW in 2017, of which about 20 GW was exported. Major export donations are Europe, Latin America, the Middle East and Japan. It is estimated that Chinese manufacturers' share in the global PV inverter market is around 61%. While in 2011, China counted only one inverter manufacturer (Sungrow) in the top 10 ranking, in 2018, five Chinese companies ranked into the top 10 ranking in the shipment volume (Huawei, Sungrow, Sineng, Goodwe and TBEA Sunoasis), the same number as 2017.

The typical products dedicated to the residential PV market have rated output powers ranging from 1 kW to 10 kW, for single phase (Europe) or split phase (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.

Inverter technologies have improved with the adoption of new power semiconductor devices such as SiC and GaN. These devices realized higher conversion efficiencies together with a reduction in size and weight, resulting in lower LCOE. Meanwhile, inverters are now required to have smart control functions as well, to realize autonomous adjustment functions for grid stabilization (voltage stabilization, frequency stabilization, power factor adjustment, output curtailment, soft start, etc.). An increasing number of manufacturers propose inverter and PV storage solutions for the market where self-consumption is the major driver. In this sector, for distributed generation, the launch of packaged products consisting of PV and storage batteries with Home Energy Management Systems (HEMS) or Building Energy Management Systems (BEMS) has been announced.

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 which are affected by shading and a more efficient rapid shutdown can be conducted in case of fire. It is estimated that about 4,8 GW of these devices were shipped in 2018, showing the market expansion from about 3,6 GW in 2017. MLPE has been particularly introduced to the US residential PV market. For example, in California, due to the requirements for

THE DOWNSTREAM SECTOR / CONTINUED

rapid shutdown, the share of MLPE is extremely high. The MLPE share in the residential PV market is 83%, consisting of about 48% by DC optimizers and 35% by microinverters.

As well as PV module suppliers, inverter manufacturers have been suffering from the significant cost pressures and severe competition. Reorganization, mergers and acquisitions of inverter manufacturers have been reported one after another. In January 2019, KACO new energy (Germany) announced that it sold the central inverter business to OCI Power (Korea). The company also announced a plan to sell the string inverter business to Siemens (Germany) and focus on the storage system business and the smart infrastructure business. In July 2019, ABB (Switzerland) agreed to sell the PV inverter business to FIMER (Italy). In February 2019, Schneider Electric (France) disclosed its plan to withdraw from the central inverter business and concentrate on the string inverter business for residential and commercial applications. In the MLPE sector, SunPower Corporation (USA) agreed in June 2018 to sell the microinverter business to Enphase Energy (USA) and completed the sales procedures in August 2018.

The consolidation of manufacturers is still underway, and the players need to differentiate their products from others. Some companies started to provide integrated solutions including operation and monitoring of PV power plants using IoT, aiming to improve their profit structures.

The production of specialized components such as tracking systems, PV connectors, DC switchgears and monitoring systems, represents an important business for many large-scale electric equipment manufacturers. With the increase of utility-scale PV power plants, the market for single-axis trackers has been growing. Along with the increase in adoption of bifacial PV modules, it is expected that the tracker system market for bifacial PV modules will expand.

TRADE CONFLICTS

Trade conflicts over PV products including polysilicon continued to give impacts on business strategies of PV companies. In this section, trends of major trade conflicts observed in 2018 are described.

In 2018, the USA, which is one of the major PV markets, implemented safeguard measures under the Section 201 of the US Trade Act of 1974 and safeguard tariff towards c-Si PV modules was introduced. The measures were implemented on February 7, 2018 and effective for four years. The tariff imposed on c-Si PV cells and modules imported to the USA is 30% in the first year, 25% in the second year, 20% in the third year and 15% in the fourth year. However, the tariff on solar cells will be exempt for up to 2,5 GW/year of import. Beneficiary countries of Generalized System of Preferences (GSP), which aims to support developing countries, and countries accounting for less than 3% of total US import are exempt from the safeguard measures. At the beginning, it was calculated that the installation cost of a utility-scale PV system in the USA will increase by about 10 USD cents/W in case a 30% tariff is imposed, and negative impacts on the electricity business market were concerned. However, due to the price reduction of PV modules in 2018 as mentioned above, the impacts of price increase were limited. Meanwhile, major Chinese and Korean PV manufacturers set up PV module manufacturing bases in the USA and the manufacturing capacity of PV cells/ modules in the USA increased from 2 GW/year as of the end of 2017 to 5 GW/year as of the end of 2018. Furthermore, it is reported that total 4 GW/year of production capacity enhancement is expected.

As for the safeguard measures, changes of the items subject to the safeguard measures and addition of countries subject to the measures were announced. In June 2018, interdigitated back contact (IBC) and busbar-less c-Si PV cells and modules were exempted from the safeguard measures. In May 2019, Turkey, which was initially exempt from the safeguard measures, was added to the list of countries subject to the measures, as well as India in June 2019. In June 2019, it was announced to exclude bifacial PV cells and modules from the subjects of the safeguard measures.

In the USA, with the third additional sanction towards China under the Section 301 of the US Trade Act of 1974, it was decided to increase the tariff to 25% from June 2019 for Chinese PV inverters, AC modules with micro inverter embedded in PV module and non-lithium storage batteries. However, the impacts are expected to be little since most Chinese PV module manufacturers have shifted their manufacturing bases for shipping to the USA to countries such as Vietnam, Malaysia, Thailand, etc. Inverter and MLPE manufacturers having manufacturing bases in China, announced to utilize their manufacturing bases in countries such as India and Mexico to avoid the imposition of the safeguard tariff. Huawei Technologies (China), which ranked first in the global inverter shipment in 2018, admitted its policy to withdraw from the US PV market due to the trade conflicts with the USA over communication equipment. As of September 2019, the Trump administration is considering an additional increase of this tariff.

Moreover, in the USA, antidumping duties (AD) and countervailing duties (CVD) measures on PV modules using Chinese solar cells which took effect in 2012, as well as AD and CVD measures on Chinese and Taiwanese c-Si solar cell and module which took effect in 2015, are still active.

In Europe, the European Commission (EC) announced that AD and CVD measures on Chinese c-Si PV cells and modules officially terminated on September 3, 2018. The MIP (minimum import price) agreement, which was established between EC and Chinese companies as a condition to exempt Chinese companies from AD and CVD measures, was also terminated. Therefore, European PV module manufacturers are forced to compete with imported products.

As for other topics, the Indian government decided to impose safeguard tariffs on PV cells and modules in July 2018. The tariff is 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 tariff will be applied to China and Malaysia, and all the other developing countries are excluded. 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 China made 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. In addition, an anti-dumping investigation is being conducted for tempered glass manufactured in Malaysia, as well as EVA used as encapsulant for PV modules manufactured in China, Malaysia, South Korea, Thailand and Saudi Arabia.

China terminated imposition of AD and CVD on European polysilicon in October 2018. Meanwhile, AD and CVD on polysilicon manufactured in the USA and Europe, which have been imposed since 2014, are continuing. China decided to extend the imposition period of AD on polysilicon by 18 months for polysilicon manufactured in Korea. The tariff rate for Korean products was revised in November 2017. This measure was scheduled to terminate in January 2019; however, the tariff is still imposed since the Chinese Ministry of Commerce decided to implement the Sunset Review (an investigation to judge whether to terminate AD measures) and the investigation is expected to end on January 19, 2020. In July 2019, REC Silicon (Norway) which has its manufacturing base in the USA, decided on a long-term closure of its polysilicon factory in Moses Lake, Washington, since trade conflicts were not resolved at the US-China summit meeting on the occasion of the G20 summit held in June 2019, and there seemed to be no prospect of selling their polysilicon products in China. REC Silicon established a joint venture with a Chinese company for a fluidized base reactor (FBR) process-based polysilicon factory in China which is currently in operation.

PV has important ramifications at the economic, social and environmental levels of our society. By the positive impacts it generates in these three areas, PV can be considered a main contributor on the path towards sustainability.

VALUE FOR THE ECONOMY

The PV sector's turnover in 2018 amounted to around 132 Billion USD, based on average system prices and other known aspects of PV development.

This value has been computed based on PV installations and their average value. The contribution of the industry is not detailed here. Investments in the industry occur irregularly with depreciation on variable time periods. This report has made the choice of assessing the value for the economy based on installations rather than an assessment of the complete value chain's contributions on an annual basis.

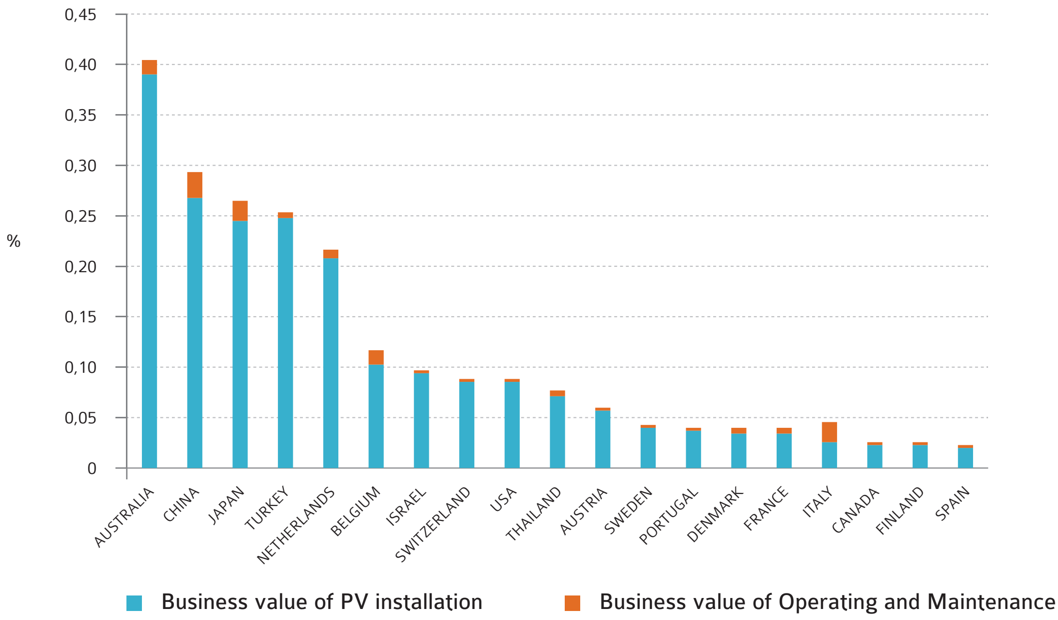
The value of O&M has increased slightly to around 7 Billion USD while the growth of the market hasn't produced a dramatic increase on the installation side.

CONTRIBUTION TO THE GDP

Figure 5.1 shows the estimated business value for PV compared to GDP in IEA PVPS reporting countries and other major markets. The shown value corresponds to the internal PV market in each country, 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.

Some countries benefited from exports that increased the business value they obtained through the internal PV market while huge imports in other countries 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 equipment's, tier-1 companies are producing in different places, buying components and materials all over the world.

FIGURE 5.1: BUSINESS VALUE OF THE PV MARKET COMPARED TO GDP IN % IN 2018



SOURCE IEA PVPS & OTHERS.

The business value of PV compared to GDP represented less than 0,4% in all considered countries and more than 0,05% in most of them. Australia doubled its value to 0,40% in 2018 due to its market uptake. In China the relative business value of PV went down to around 0,28% of the GDP, coming from 0,35% last year, due to the market contraction. Japan is following with 0,25%, remaining steady compared to 2017. Turkey dropped slightly to 0,25%, while the Netherlands more than doubled its value to 0,21% this year. Belgium, Switzerland, USA, Thailand and Austria are located between 0,05% and 0,10% like last year, with slight upwards or downwards trends. Israel markedly increased its performance from 0,035% to 0,095% while France experienced a slight drop from 0,045% to 0,035%. In a nutshell, the share of PV in the GDP of the key countries grew slightly with some higher contributions in some countries considered. It shows that the investment in the energy transition, even if these numbers would be multiplied by a factor of 10, would stay in a reasonable range and wouldn't change significantly the availability of financial resources.

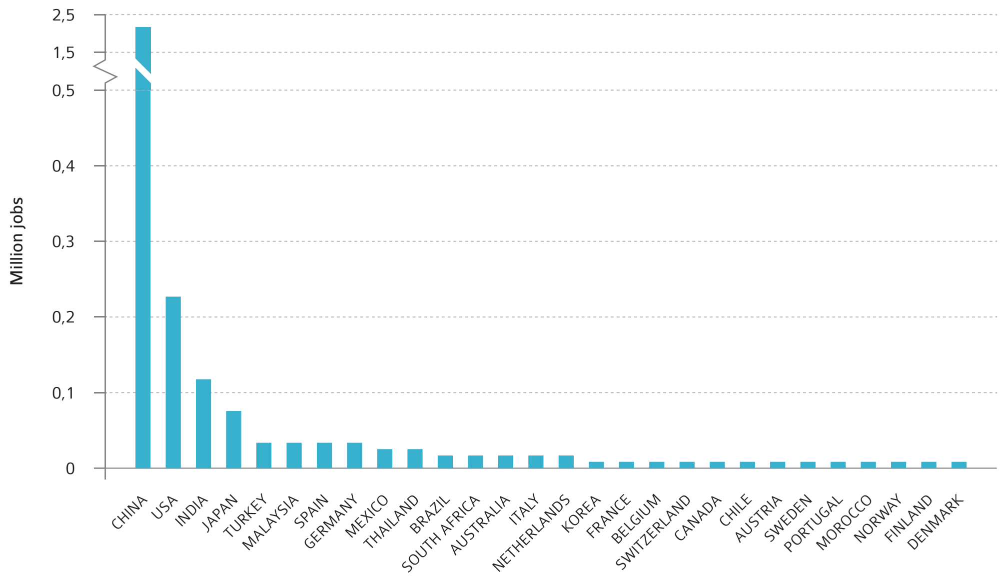
The business value of the industry is in general more complex to assess, due to decentralized production and transnational companies. In this respect it is not considered here.

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 7 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. This value doesn't consider the material cost of replacement and repowering, which is hardly visible. The value of recycling could be added as well.

VALUE FOR THE ECONOMY / CONTINUED

FIGURE 5.2: GLOBAL EMPLOYMENT IN PV PER COUNTRY



SOURCE IEA PVPS NSRS AND IRENA RESOURCE DATABASE.

EMPLOYMENT IN PV

Figure 5.2 gives an overview of the total jobs reported by the IEA PVPS countries, with the addition of India and Brazil. Reported numbers have been sourced from the IEA PVPS National Summary Reports and IRENA REsource database. It should be noted that these numbers are strongly dependent on the assumptions and field of activities considered in the upstream and downstream sectors.

As the leading producer of PV products and the world's largest installation market, China is markedly leading PV employment with around 2,2 million jobs in 2018, which represents about two thirds of the PV jobs worldwide. Lower by one order of magnitude, USA comes second in the ranking with about 225 000 jobs. India and Japan are on the third and fourth places respectively, with numbers around 115 000 and 76 000 FTE. The European Union shows a total PV employment of about 118 000 FTE. Similarly, in good correlation with the market evolutions, PV employment also expanded in India, South-East Asia and Brazil in 2018.

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.

When specifically focusing on the development and installation activities, which are more labour intensive than manufacturing, it can be observed that the average FTE intensity per installed MW is around 10. But these numbers vary considerably from one country to another and additionally from one market segment to another. Small scale PV generates more jobs than utility-scale PV in general. O&M generates many manual jobs while the entire PV value chain creates good quality jobs, from research centers to manufacturing.

With an estimated total of 3,6 million jobs in the solar PV sector worldwide in 2018, PV employs around one third of the total renewable energy workforce and remains the number one in the employment ranking of the global renewable energy sector.[4] Compared to 2017, a 7% growth of global employment in PV is observed.

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 in recent years through different schemes for local manufacturing: Canada, France, Morocco, Turkey and 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.

4 IRENA – *Renewable Energy and Jobs – Annual Review 2019.*

PV FOR SOCIAL POLICIES

Besides its direct value in the economy and the jobs that it creates, both making contribution to the prosperity of the countries in which it is being installed and produced, PV entails additional positive implications on social level. Several examples can be highlighted.

As shown through the off-grid PV market development in Africa and Asia (see chapter 2), PV can be a competitive alternative to provide energy access to rural areas not connected to power grids. Improved energy access can benefit rural business performance, free up workers' time, encourage more studying hours for children, and create or enhance jobs as a result. Electrification is a key factor to reduce poverty and increase education, with a direct impact on women's and children's rights. In that respect, PV would deserve a significant attention for electrification.

In China, since the end of 2015, 100% electrification of the country has been reached. So, there are no government supported projects for off-grid rural electrification anymore since 2016. However, a massive program for poverty alleviation leaning on PV was launched. It aims to enhance the standard of living of around 2.8 million poor households by installing around 5kW of PV for each family. This leads to an additional annual income of over 3000 RMB for these households through the selling of the generated PV electricity. More than 15 GW of PV have already been approved within this program.

A similar social program called 'MySuria' was launched in Malaysia in 2017 but it was discontinued in 2018.

In Italy, the Municipality of Porto Torres (Sardinia Region) introduced the so called "reddito energetico" (energy income) project, based on a revolving fund, which is used to finance the installation of PV systems for families in energy poverty conditions. The mechanism allows to self-consume the electricity in real time, in order to reduce the cost of the electricity bill, and to finance the revolving fund through revenues of the net-billing scheme. The first tender took place in 2017. After this project, some other municipalities and regions are planning and carrying out similar initiatives. The municipality of Rome was quite active in that perspective with a project to power schools.

Chile also provides subsidy for improving low income family houses through energy innovation measures that include PV systems installations for reducing household's electricity costs through self-generation.

In general, the low cost of PV electricity could be better used to alleviate poverty, in developed and developing countries. It offers opportunities for social programs, and especially to fight energy poverty, which has not been widely used yet. While the reputation of PV, especially in the European countries that started to fund its development, is the one of a costly energy source, increasing electricity prices, the reality of PV in 2019 is that it represents a tremendous opportunity to reduce energy prices for the poorest citizens, reduce energy costs for public buildings, from schools to retirement homes, and increase the access to electricity for everyone.

CLIMATE CHANGE MITIGATION

Climate change has become one of the key challenges faced by humankind. Drastically reducing our greenhouse gas emissions represents a vital priority, as has been once again emphasized by the latest IPCC reports.

The power sector contributes to about 38% of the global energy-related CO_2 emissions, with around 13 Gt CO_2 emitted[5] by the combustion of coal, gas and oil in power plants.

Increasing the PV share in the grid mix will significantly reduce the emissions from electricity generation. The current global average carbon intensity of electricity is 475 gCO_2/kWh whereas for 1 kWh produced by PV the emitted CO_2, considered on a life cycle basis, can be as low as 15g depending on technology and irradiation conditions. These numbers have been computed with the data of the IEA PVPS Task 12 on sustainability and the databases made available by the groups' researchers.

Considering the cumulated capacity installed all over the world at the end of 2018 and considering country specific grid mixes and irradiation conditions, calculations show that the yearly CO_2 emissions avoided by PV are above 590 Mt. While today PV represents slightly less than 3% of the generated electricity, it avoids around 4,5% of the power sector emissions. This is linked to the fact that PV is being massively installed in countries having highly carbon intensive grid mixes, like China and India.

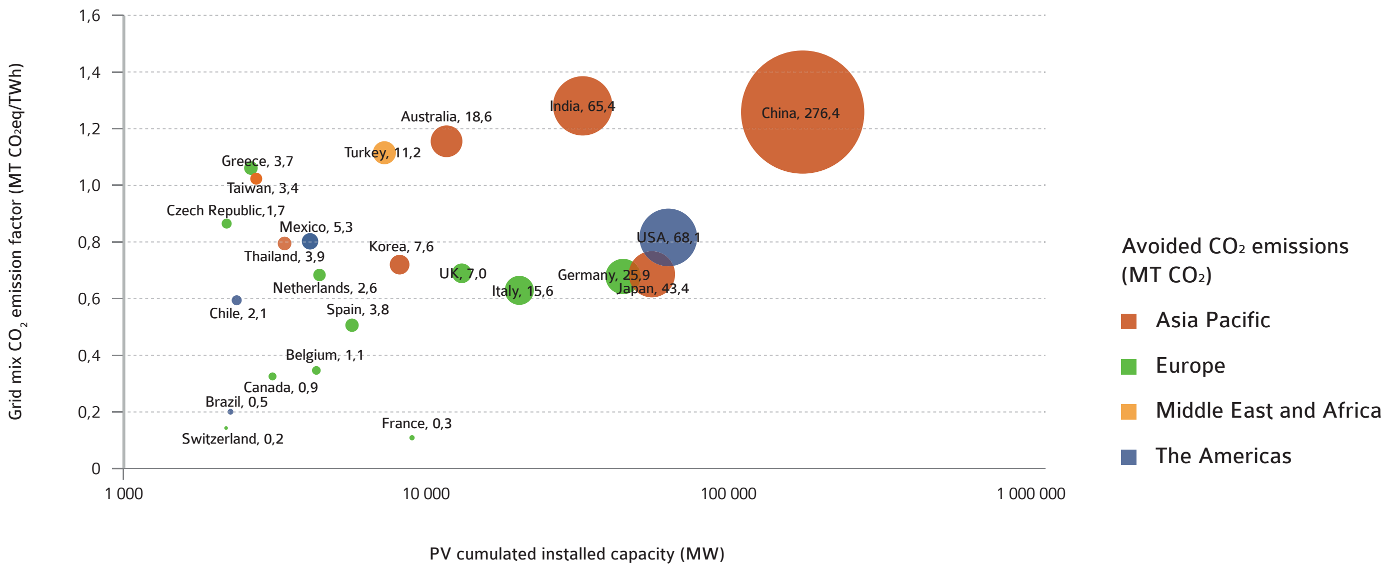
Figure 5.3 gives a view of the avoided CO_2 emissions for the 25 countries ranking highest in cumulated installed PV capacity and representing 97% of the total avoided emissions. This figure clearly shows the differential contribution of the different countries to the global avoided emissions and the high impact of their respective grid mix CO_2 emission factors.

The key conclusion is that the PV installed capacity avoids today more than 590 Million Tons of CO_2 eq. This is significantly more than the previous numbers computed with average CO_2 emissions. The explanation is rather simple: PV avoids emissions depending on the national power mix. The more CO_2 the power mix in a country emits, the more positively PV installations will contribute to avoiding emissions. Hence, developing PV in China or Germany has a significant impact and global numbers show a higher percentage of avoided emissions than the share of PV in the electricity mix.

5 IEA, *Global Energy 8 CO_2 Status Report 2018.*

CLIMATE CHANGE MITIGATION / CONTINUED

FIGURE 5.3: CO_2 EMISSIONS AVOIDED BY PV



SOURCE IEA PVPS & OTHERS.

six

COMPETITIVENESS OF PV ELECTRICITY IN 2018

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 financial solutions, especially to emerging challenges.

This section aims at defining where PV stands regarding 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 averaged and should always be looked at as segment related.

However, the question of competitiveness should always be 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 too important not to be controlled. PV competitiveness should therefore be considered in this same respect, 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

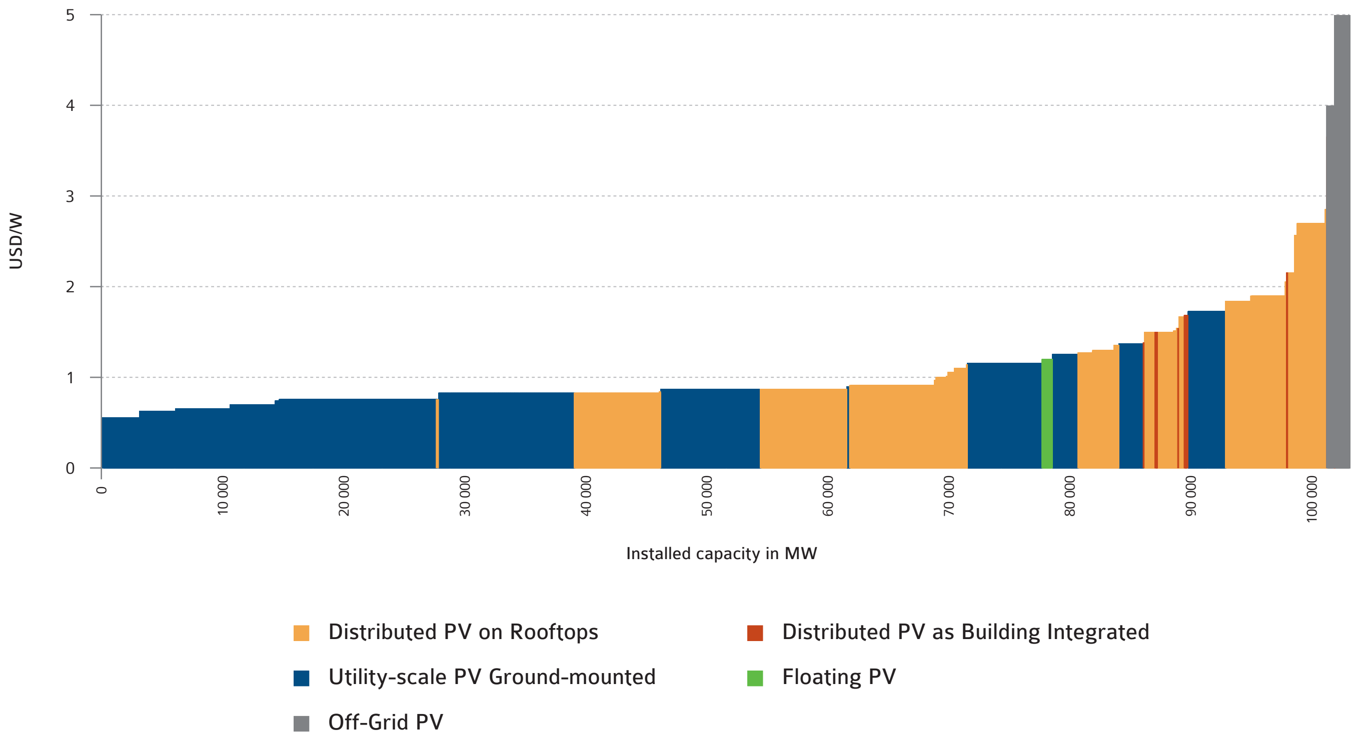
Reported prices for PV systems vary widely and depend on a variety of factors including system size, location, customer type, connection to an electricity grid, technical specification and the extent to which end-user prices reflect the real costs of all the components. For more detailed information, the reader is directed to each country's national survey report on the IEA PVPS website (www.iea-pvps.org).

Figure 6.1 shows the range of system prices in the global PV market in 2018. It shows that almost 70% of the PV market consists in prices below 1 USD/W. Distributed PV systems start around 0,75 USD/W while utility-scale PV saw prices as low as 0,55 USD/W. Lower figures have been seen in 2019 already. Floating PV and BIPV are given as indications given the low market development of these solutions. BIPV can be seen as a series of segments where the prices can significantly diverge. Off-grid applications suffer from a similar situation, with totally different cases illustrated in different prices. In general, the price range decreased from the previous year for all applications.

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. In 2018, the lowest system prices in the off-grid sector, irrespective of the type of application, typically ranged from about 1,11 USD/W to

SYSTEM PRICES / CONTINUED

FIGURE 6.1: 2018 PV MARKET COSTS RANGES



SOURCE IEA PVPS & OTHERS.

17,36 USD/W. The large range of reported prices in Table 6.1 is a function of country and project specific factors. The highest haven't been included in the figure given the very low level of installations: in general, off-grid prices have been averaged in the figure for readability reasons.

Floating PV would require some further developments to identify real-life prices since the only indications provided seem a bit higher than 2018 market prices as collected.

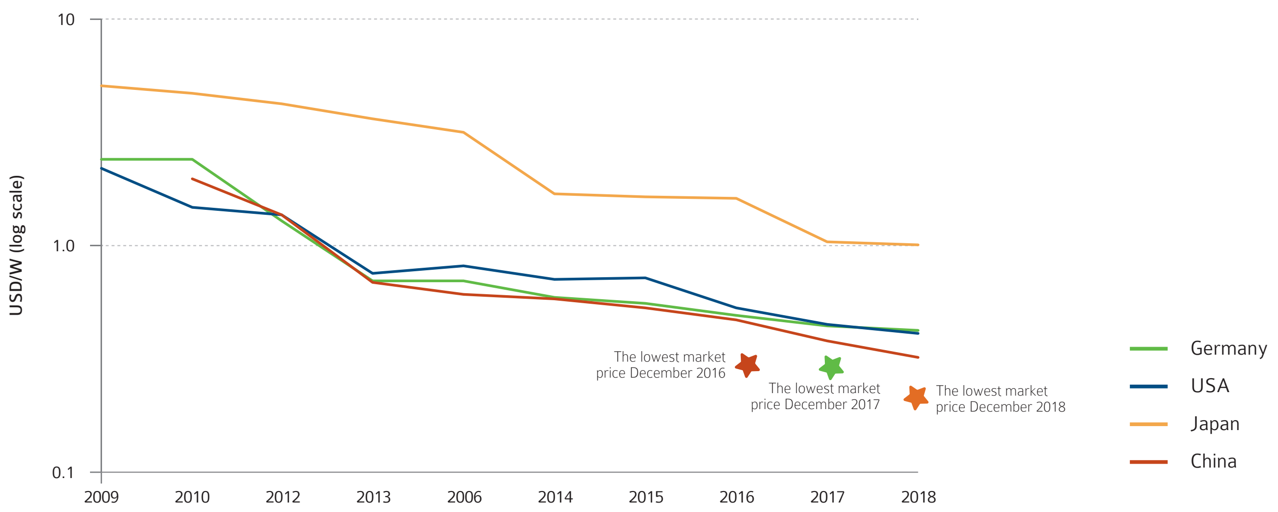
Additional information about the systems and prices reported for most countries can be found in the various National Survey Reports; excluding VAT. More expensive grid-connected system prices are often associated with roof integrated slates, tiles, one-off building integrated designs or single projects: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

The lowest achievable installed price of grid-connected systems in 2018 also varied between countries as shown in Table 6.1. 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 2018, 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 0,6 USD/W 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. Finally, the question of the lowest CAPEX is not always representative of the lowest LCOE: the case of utility-scale PV with trackers illustrates this, with additional CAPEX translating into a significantly higher LCOE. Bifacial costs are not visible in a system cost figure.

Figure 6.2 illustrates the prices for PV modules in 4 indicative countries: it shows that prices continued to decline in 2018 in several countries.

On average, the price of PV modules in 2018 (shown in Table 6.1) accounted for approximately between 40% and 50% of the lowest achievable prices that have been reported for grid-connected systems. In 2018, the lowest price of modules in the reporting countries was about 0,22 USD/W. It is assumed that such prices are valid for high volumes and late delivery (not for installations in 2018). However, module prices for utility-scale plants have been reported below the average values, down to less than 0,20 USD/W at the end of 2018.

FIGURE 6.2: EVOLUTION OF PV MODULES PRICES IN 4 INDICATIVE COUNTRIES IN USD/W



SOURCE IEA PVPS & OTHERS.

TABLE 6.1: INDICATIVE INSTALLED SYSTEM PRICES IN SELECTED IEA PVPS REPORTING COUNTRIES IN 2018

	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	1,72	1,28	1,77	1,32	N/A	N/A	1,85	1,38	N/A	N/A	N/A	N/A
AUSTRIA	1,57	1,85	1 - 1,267	1,18 - 1,49	N/A	N/A	N/A	N/A	5,00	5,90	N/A	N/A
BELGIUM	1 - 1,5	1,18 - 1,77	0,95 - 1,2	1,12 - 1,42	0,75 - 0,8	0,88 - 0,94	N/A	N/A	N/A	N/A	N/A	N/A
CANADA	2,93	2,26	2,21	1,70	1,46	1,12	1,46	1,12	N/A	N/A	N/A	N/A
CHINA	5,5 - 6	0,83 - 0,91	5,5 - 6	0,83 - 0,91	5,5 - 6	0,83 - 0,91	5 - 5,5	0,76 - 0,83	N/A	N/A	N/A	N/A
DENMARK	5 - 11	0,79 - 1,74	4 - 10	0,63 - 1,58	5 - 9	0,79 - 1,42	4 - 5	0,63 - 0,79	7 - 20	1,11 - 3,17	N/A	N/A
FRANCE	1,7 - 3,5	2 - 4,13	1 - 1,4	1,18 - 1,65	0,9 - 1,2	1,06 - 1,42	0,6 - 1	0,71 - 1,18	N/A	N/A	N/A	N/A
FINLAND	1,05 - 1,61	1,24 - 1,9	0,75 - 1,05	0,88 - 1,24	0,65 - 0,75	0,77 - 0,88	0,55 - 0,65	0,65 - 0,77	5,00	5,90	N/A	N/A
ISRAEL	5 - 6	1,39 - 1,67	3,5 - 3,8	0,97 - 1,06	3 - 3,2	0,83 - 0,89	2,6 - 2,77	0,72 - 0,77	N/A	N/A	N/A	N/A
ITALY	1,2 - 1,6	1,42 - 1,89	1 - 1,25	1,18 - 1,47	0,8 - 1	0,94 - 1,18	0,55 - 0,8	0,65 - 0,94	N/A	N/A	N/A	N/A
JAPAN	251,00	2,27	222,00	2,01	222,00	2,01	202,00	1,83	N/A	N/A	N/A	N/A
MALAYSIA	6,00	1,43	4 - 5,5	0,96 - 1,31	3,60	0,86	2,85 - 2,95	0,68 - 0,7	N/A -	N/A	N/A -	N/A
NETHERLANDS	1,54	1,82	0,98	1,15	0,98	1,15	N/A	N/A	0,00	N/A	0,00	N/A
PORTUGAL	1,40	1,65	1,1 - 1,2	1,3 - 1,42	1,00	1,18	0,6 - 0,8	0,71 - 0,94	2,00	2,36	0,00	N/A
SPAIN	1,5 - 2	1,77 - 2,36	0,75 - 1	0,88 - 1,18	0,75 - 1	0,88 - 1,18	0,65 - 0,75	0,77 - 0,88	N/A -	N/A	N/A	N/A
SWEDEN	14,80	1,70	12,1 - 12,2	1,39 - 1,4	10,3 - 10,7	1,18 - 1,23	8 - 9,3	0,92 - 1,07	25,00	2,87	20,00	2,30
SWITZERLAND	2,2 - 3,5	2,25 - 3,58	1 - 2,5	1,02 - 2,55	0,7 - 1,3	0,72 - 1,33	N/A	N/A	10 - 15	10,21-15,32	8 - 17	8,17 - 17,36
THAILAND	52,00	1,61	45 - 47	1,39 - 1,45	32,00	0,99	28 - 30		N/A	N/A	N/A	N/A
USA	2,70	2,70	1,83 - 1,95	1,83 - 1,95	1,72	1,72	1,06 - 1,25	1,06 - 1,25	N/A	N/A	N/A	N/A

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

SOURCE IEA PVPS.

SYSTEM PRICES / CONTINUED

TABLE 6.2: INDICATIVE MODULE PRICES (NATIONAL CURRENCY/WATT AND USD/WATT) IN SELECTED REPORTING COUNTRIES

COUNTRY	CURRENCY	LOCAL CURRENCY/W	USD/W
AUSTRALIA	AUD	0,35 - 1,15	0,3 - 0,9
AUSTRIA	EUR	0,47	0,6
CANADA	CAD	0,61 - 0,65	0,5 - 0,5
CHINA	CNY	2,1	0,3
DENMARK	DKK	1 - 3	0,2 - 0,5
FINLAND	EUR	0,25 - 0,35	0,3 - 0,4
ISRAEL	ILS	1,22	0,3
ITALY	EUR	0,2 - 0,48	0,2 - 0,6
JAPAN	JPY	128	1,2
MALAYSIA	MYR	0,29	0,3
NETHERLANDS	EUR	0,76	0,9
PORTUGAL	EUR	0,3 - 0,5	0,4 - 0,6
SPAIN	EUR	0,23 - 0,34	0,3 - 0,4
SWEDEN	SEK	3,2 - 6,6	0,4 - 0,8
SWITZERLAND	CHF	0,4 - 0,75	0,4 - 0,8
TURKEY	TRY	0,35 - 0,55	0,1 - 0,1
USA	USD	0,31 - 0,61	0,3 - 0,6

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

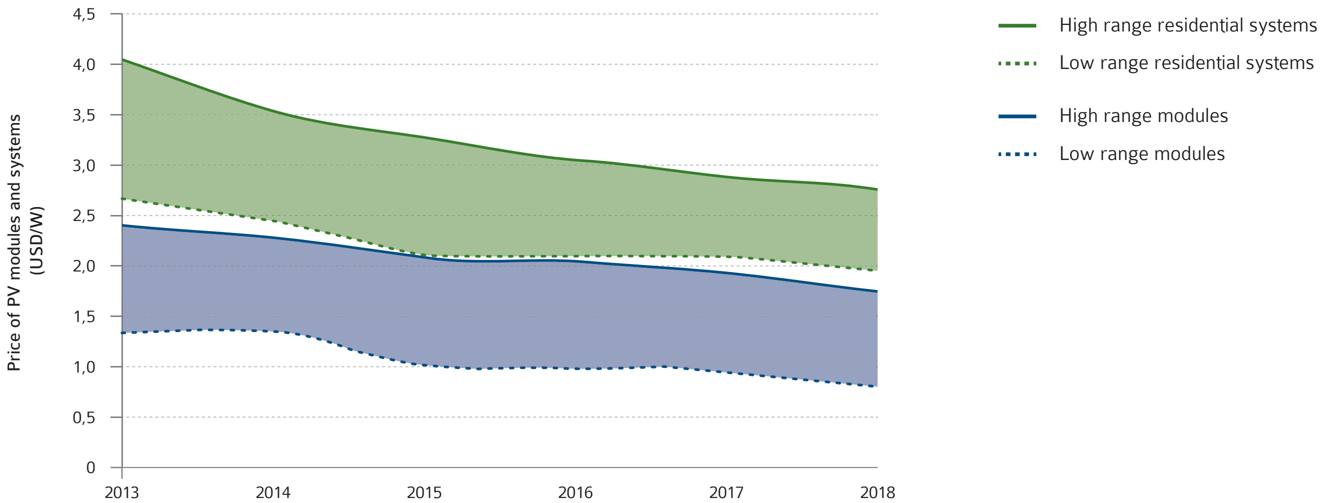
SOURCE IEA PVPS.

The Chinese decision in May 2018 led to 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 global PV market was stagnating. Prices below 0,22 USD/W 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 are significantly lower than previously existing ones. One can also assume that the most competitive Thin Film technologies can outperform traditional crystalline silicon ones.

Higher module prices are still observed depending on the market. For instance, the prices in Japan are consistently higher than in Germany and the United States, while average selling prices are in general still in the 0,3 USD/W range for most producers.

Figure 6.3 shows the evolution of prices for PV modules in selected key markets. It shows that, like the modules, system prices continued to go down, however at a slightly slower pace. Such evolution happened in all segments.

FIGURE 6.3: EVOLUTION OF PV MODULES AND SMALL-SCALE SYSTEMS PRICES IN SELECTED REPORTING COUNTRIES 2013 - 2018 USD/W



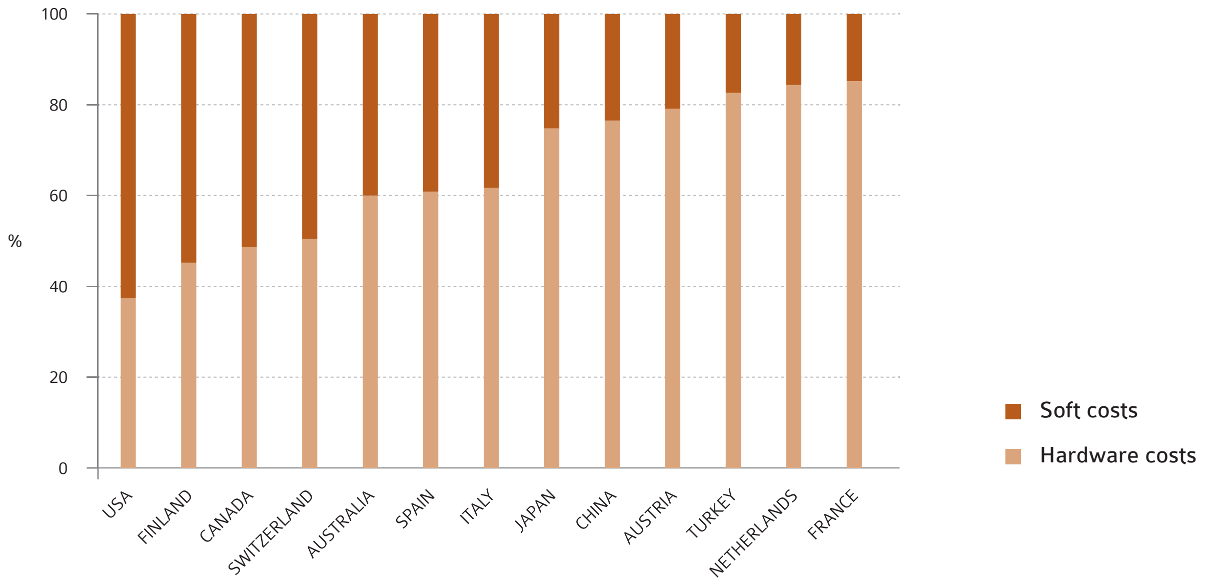
SOURCE IEA PVPS & OTHERS.

RESIDENTIAL PV SYSTEMS

System prices for residential PV systems reveal huge discrepancies from one country to another: the final price of modules, 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.

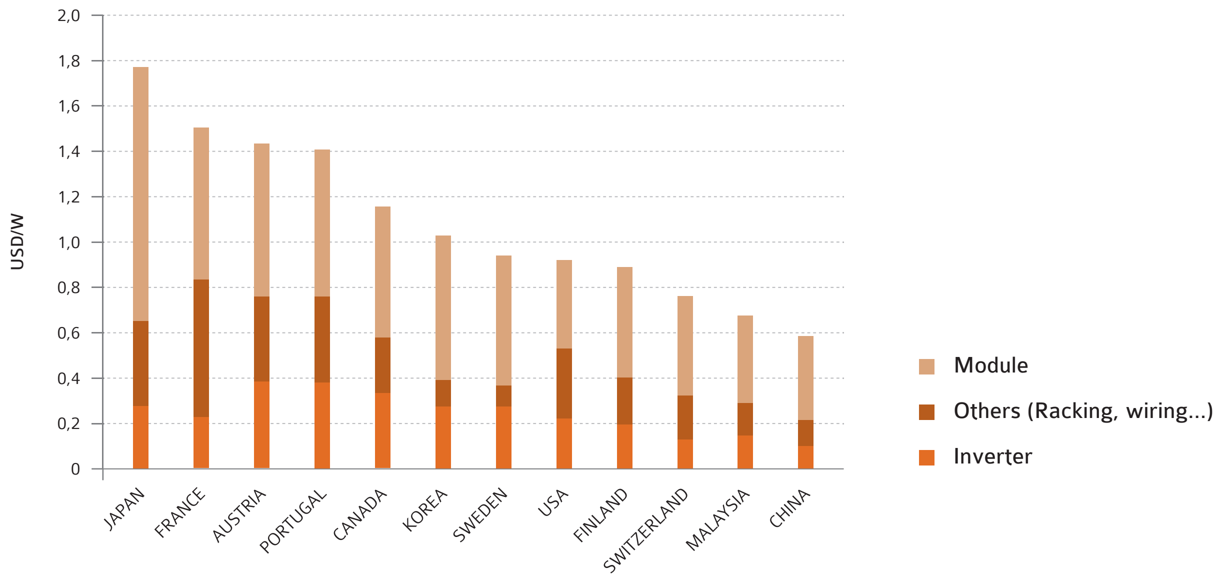
When analysing figures 6.4 and 6.5, not surprisingly hardware costs represent a more important share in the total costs in the countries with higher hardware costs such as Japan, France and Austria.

FIGURE 6.4: AVERAGE COST BREAKDOWN FOR A RESIDENTIAL PV SYSTEM < 10KW



SOURCE IEA PVPS.

FIGURE 6.5: 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.

GRID PARITY – SOCKET PARITY

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

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

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

Technical solutions will allow for increases in the self-consumption level (demand-side management including EV charging or direct use to heat water with heat pumps, 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 incentives for some renewable sources);

Figure 6.6 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 three different system prices (0,5, 1 and 2 USD/W, 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 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 is already 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: either prices during PV production will stay down and impair the ability to remunerate the investment or low prices will attract additional demand and will stabilize the market prices. At this point, both options remain possible without possibilities to identify which one will develop.

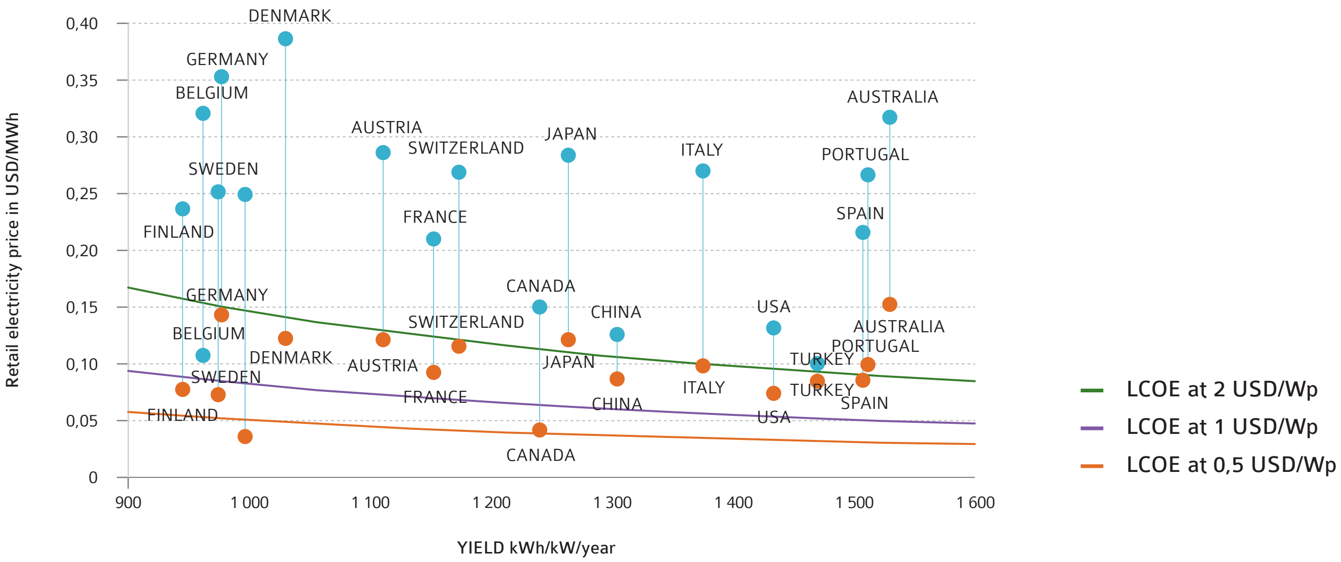
When a wholesale market doesn't exist as such, (in China for instance), the comparison point is the production cost of electricity from coal-fired power plants. Several plants were being built or foreseen, in particular in Spain, with a business model based on market sales.

FUEL-PARITY AND OFF-GRID SYSTEMS

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

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

FIGURE 6.6: 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.

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.

PRODUCING COMPETITIVE GREEN HYDROGEN WITH PV

The declining cost of PV electricity opens the door for other applications and especially the possible production of "green" hydrogen directly from PV (possibly in combination with wind). While the business model behind is being explored, in particular in Chile, Morocco and France, the cost of PV electricity should reach lower levels, while the cost of electrolysers should decrease as well to make green hydrogen competitive. This perspective is not so far away, and some start to envisage a possible competitiveness in the coming years for specific uses of hydrogen. While the competitiveness with "black" hydrogen seems still unreachable for the time being, other uses in transport, some industrial applications and possibly agriculture (through ammonia), might create a tremendous opportunity for PV to produce hydrogen without being connected to the grid. Such a development would increase possibly the PV market significantly outside of the constraints it experiences for the time being.

RECORD LOW TENDERS

With several countries having adopted tenders as a way to allocate PPAs to PV projects, the value of these PPAs achieved record low levels until 2019. 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 0,6 USD/W) and a low cost of capital. At the moment of writing these lines, the latest record were 17,5 USD/MWh for PV projects in Brazil, 18,2 USD/MWh in Portugal and 24,4 USD/MWh in Tunisia to be built in the coming years, under specific conditions. Many other winning bids globally reached a level below 40 USD/MWh. Low PPAs were granted in 2018 in the USA but with the help of the tax credit. In Europe. Projects linked to tenders represent the most competitive PV installations and their share is growing as more and more market segments are shifting to this type of procurement. See Table 3.1 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: Many European countries 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. Italy remains the number one country in the IEA PVPS network with 9,2% of PV penetration based on the installed capacity at the end of 2018. Germany is following with almost 8,4%. Japan reached the 7,8% mark and Australia follows with 6,5% PV penetration. Chile reaches the 5,5% mark and Belgium 5%, followed by Israel (4,4%), Switzerland (4,3%), Netherlands (3,9%), China (3,6%), Spain (3,6%) and Denmark (3,2%).

Outside the IEA PVPS network, Honduras with 11%, the islands of Malta with 9% and Greece with 6,7% rank in the top three countries with PV penetration calculated on the installed capacity reached in 2018. Bulgaria almost reached the 4,3%, followed by UK (3,8%) and Czech Republic (3,6%).

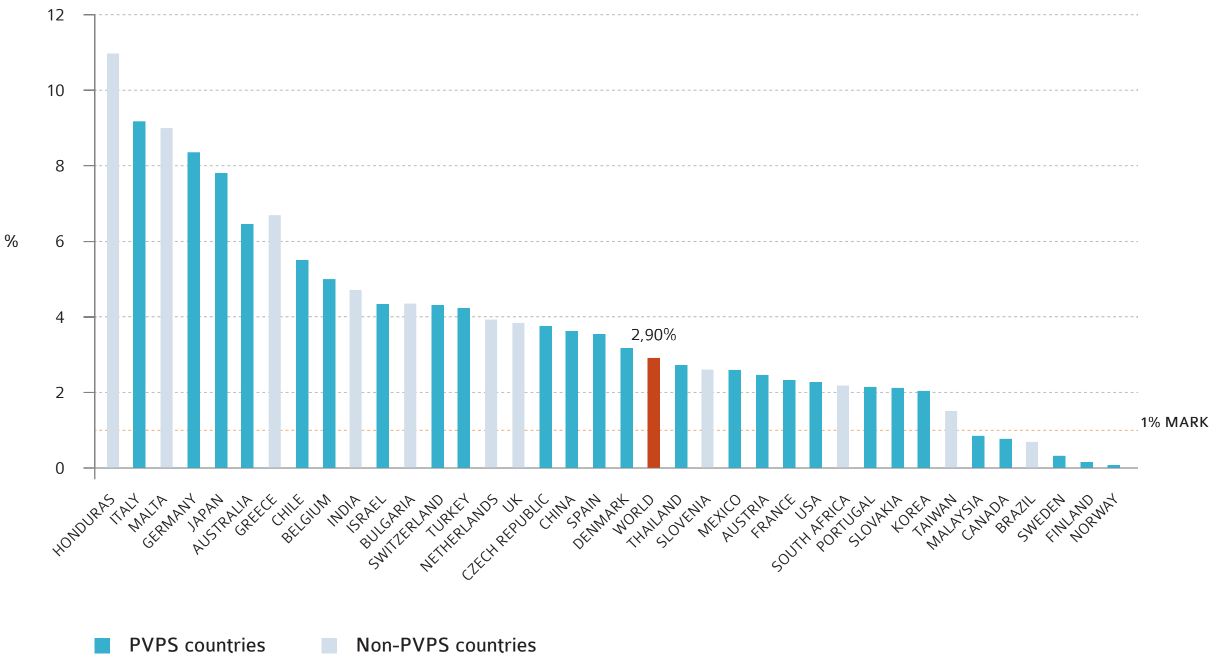
How much electricity can be produced by PV in a defined country?

- Estimated PV installed and commissioned capacity on 31.12.2018.
- 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.

Finally, Thailand, Austria, France, USA, Korea and Portugal are below the 3%, followed by Mexico, South Africa, Canada, Malaysia, Sweden, Finland and Norway which are 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 2018.

Real figures might be lower since some installations didn't produce electricity during the entire year, but also since some plants might have experienced production issues, due to technical problems or external constraints. The real PV production in a country is difficult to assess, especially when self-consumption and storage enter into consideration. IEA PVPS advocates for governments and energy stakeholders, including grid operators to create accurate databases and measure precisely PV production.

FIGURE 7.1: PV CONTRIBUTION TO THE ELECTRICITY DEMAND IN 2018



SOURCE SOURCE IEA PVPS 8 OTHERS.

Figure 7.1 shows how PV theoretically contributes to the electricity demand in IEA PVPS countries, based on the PV capacity at the end of 2018.

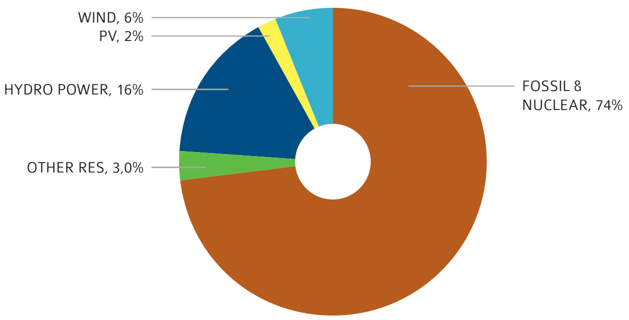
GLOBAL PV ELECTRICITY PRODUCTION

With around 512,3 GW installed worldwide, PV could produce more than 670 TWh (see Table 7.1) of electricity on a yearly basis. With the world's electricity consumption of almost 23 000 TWh in 2018, this represents close to 3% of the electricity global demand covered by PV (Figure 7.2).

Figures 7.3 shows the new renewable installed capacity in 2018. Solar PV was the top source of new power generating capacity in 2018. For the fourth year in a row, new installed renewable energy sources outpaced net additions of fossil fuels and nuclear power combined.[6]

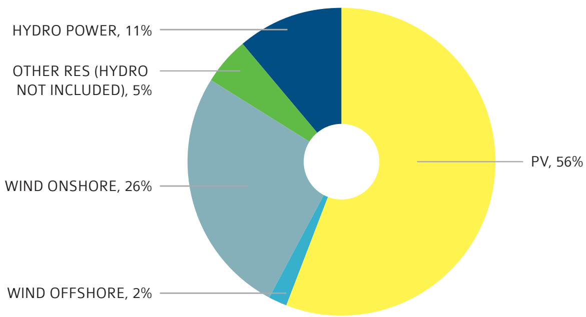
In 2018, PV represented 55% of the world's newly installed capacity of renewables, excluding hydropower. Wind power represented 28% with 51,3 GW installed.

FIGURE 7.2: SHARE OF PV IN THE GLOBAL ELECTRICITY DEMAND IN 2018



SOURCE REN21, IEA PVPS.

FIGURE 7.3: NEW RENEWABLE INSTALLED CAPACITY IN 2018



SOURCE REN21, IEA PVPS.

6 Source: R*EN21Global Status Report.*

GLOBAL PV ELECTRICITY PRODUCTION
/ CONTINUED

TABLE 7.1: PV ELECTRICITY STATISTICS IN IEA PVPS REPORTING COUNTRIES 2017

COUNTRY	FINAL ELECTRICITY CONSUMPTION 2017	HABITANTS 2018	GDP 2018	SURFACE	AVERAGE YIELD	PV ANNUAL INSTALLED CAPACITY 2018	PV CUMULATIVE INSTALLED CAPACITY 2018	PV ELECTRICITY PRODUCTION	ANNUAL CAPACITY PER HABITANT	CUMULATIVE CAPACITY PER HABITANT	CUMULATIVE CAPACITY PER KM²	THEORETICAL PV PENETRATION
	TWh	MILLION	BUSD	KM²	KWh/KWp	MW	MW	TWh	W/Hab	W/Hab	KW/KM²	%
AUSTRALIA	259	25	1 432	7 690 000	1 531	3 775	10 953	16,8	151,0	438,3	1,4	6,5%
AUSTRIA	65	9	456	83 879	1 111	169	1 440	1,6	19,1	162,8	17,2	2,5%
BELGIUM	84	11	532	30 528	962	435	4 338	4,2	38,1	379,8	142,1	5,0%
CANADA	507	37	1 709	9 985 000	1 243	161	3 095	3,8	4,3	83,5	0,3	0,8%
CHILE	73	19	298	756 096	1 699	597	2 371	4,0	31,9	126,6	3,1	5,5%
CHINA	6 308	1 393	13 608	9 562 911	1 305	44 260	175 400	228,8	31,8	125,9	18,3	3,6%
DENMARK	32	6	351	43 090	1 030	91	991	1,0	15,7	170,9	23,0	3,2%
FINLAND	82	6	276	338 420	944	53	134	0,1	9,6	24,3	0,4	0,2%
FRANCE	443	67	2 778	549 087	1 153	862	8 961	10,3	12,9	133,8	16,3	2,3%
GERMANY	531	83	3 997	357 170	978	2 960	45 452	44,4	35,7	548,1	127,3	8,4%
ISRAEL	56	9	370	22 070	1 797	406	1 358	2,4	45,7	152,8	61,5	4,4%
ITALY	302	60	2 074	301 340	1 376	425	20 107	27,7	7,0	332,7	66,7	9,2%
JAPAN	906	127	4 971	377 962	1 262	6 662	56 162	70,9	52,7	443,9	148,6	7,8%
KOREA	563	52	1 619	100 266	1 416	2 265	8 099	11,5	43,9	156,9	80,8	2,0%
MALAYSIA	144	32	354	330 800	1 413	503	860	1,2	16,0	27,3	2,6	0,8%
MEXICO	270	126	1 224	1 964 380	1 708	3 617	4 103	7,0	28,7	32,5	2,1	2,6%
NETHERLANDS	111	17	913	41 500	994	1 511	4 414	4,4	87,7	256,2	106,4	3,9%
NORWAY	122	5	435	385 178	882	23	67	0,1	4,3	12,5	0,2	0,0%
PORTUGAL	48	10	238	92 220	1 513	88	673	1,0	8,6	65,5	7,3	2,1%
SPAIN	242	47	1 426	505 940	1 508	288	5 659	8,5	6,2	121,1	11,2	3,5%
SWEDEN	130	10	551	447 420	974	158	426	0,4	15,5	41,8	1,0	0,3%
SWITZERLAND	59	9	706	41 285	1 173	271	2 177	2,6	31,8	255,7	52,7	4,3%
SOUTH AFRICA	193	58	366	1 219 090	1 733	60	2 409	4,2	1,0	41,7	2,0	2,2%
THAILAND	194	69	505	513 120	1 522	403	3 459	5,3	5,8	49,8	6,7	2,7%
TURKEY	249	82	767	783 560	1 471	2 943	7 149	10,5	35,7	86,8	9,1	4,2%
USA	3 971	327	20 494	9 831 510	1 437	10 680	62 498	89,8	32,6	191,0	6,4	2,3%
WORLD	22 964	7 637	80 684	134 325 435	1 300	103 226	512 294	666,0	13,5	67,1	3,8	2,9%

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 Austria, some electricity utilities started public participation models for PV, others are selling PV systems. The electric cars development might further push PV, since many utilities offer EV services, install charging stations; the direct link to the use of electricity out of renewables is visible. Nearly all larger utilities are meanwhile promoting PV for private houses, industries or multifamily solutions.

In Denmark, the distribution utilities, notably Norlys (formerly EnergiMidt), have also promoted the use of PV and has included the technology in its business portfolio, and since 2009 several distribution utilities have included PV technology in their portfolio of products. The utility made for a couple of years use of a capital incentive to customers inside its service area but is now marketing

PV technology without any special support. Most distribution utilities simply regard PV as a relevant standard product and some offer finance packets and payment via the electricity bill.

In Finland, several utility companies have started to sell and install turnkey PV systems as a product for residential houses and commercial buildings. They either make the installations by themselves or have contracts with installation companies. In June 2017, most utility companies have announced offers to buy surplus electricity from micro-PV plants. In general, the utilities pay the Nord Pool Spot Finland area price of the surplus electricity without VAT 24 %, which is roughly one-third of the retail electricity price.

In France, EDF and ENGIE are both major international players, with a wide international portfolio covering both fossil (and nuclear) and renewable energies. There are no legal or regulatory barriers to their active involvement in photovoltaics generation in France, although EDF must demonstrate a complete separation of its public service delegations (network management, electricity contracts on government regulated prices) and commercial activities. EDF Renouvelables (EDF Renewable for the international branch), a subsidiary of EDF, EDF Renouvelables Services (O&M services in Europe), and EDF Energie Nouvelles Réparties (EDF ENR), its own subsidiary, are both active in France. EDF ENR is active in the residential market. A second subsidiary company, EDF EN Photowatt, is a photovoltaics manufacturer. EDF is also active in R&D activities through both EDF internal research departments, research partnerships with public research organisations and Photowatt. Through its different subsidiaries, EDF has installed more than 2 GW worldwide, and owns roughly half this capacity. ENGIE is the biggest solar generator in France, with over 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.

In Germany, where the penetration of PV provides already around 8,7% 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 decentralized 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 Sweden, several utility companies started in 2012 to market small turnkey PV systems suited for roofs of residential houses. These utility companies have in common that most of them collaborate with local Swedish installation companies that provide the actual system and execute the installation. Only a few of them have the installation competence and product distribution lines in-house. One utility company, Umeå Energi also offer leasing of PV system to private persons.

Furthermore, in 2011, several utility companies started introducing compensation schemes for buying the excess electricity produced by micro-producers. This trend continues, and more and more utility companies now have various offers for the micro-producer's excess electricity, their green electricity certificates and guarantees of origin.

A few utilities have started to work with centralized PV parks. Since there are no subsidies for large-scale PV parks in Sweden, except for the green electricity certificate system and some direct capital subsidies, the utility companies had to test different financial arrangements and business models such as share-owned PV parks, power purchase agreements and PV electricity offers to end consumers.

In Switzerland, an increasing number of electricity utilities are entering the PV business. Especially the larger utilities who 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. Due to the private-public status of most of the utilities (they are typically owned by the communities and the cantons) this development is not always viewed positively by the incumbent PV installation companies.

In Japan, following full liberalization of electricity retailing in 2016, new players entered electricity retailing business one after another. The number of registered electric retailers was 538 (as of December 2018) and these Power Producers and Suppliers (PPS) and the former General Electricity Utilities that used to conduct regional monopolistic business are competing in the electricity market. Although the share of PPS increased to 14,8 % (as of December 2018), the situation of the electricity market in which former General Electricity Utilities are dominant remains unchanged and the same situation is observed in the power generation sector. The share of trading quantity on the Japan Electric Power Exchange (JEPX) rose to 34,2 % (as of December 2018). The effects of gross bidding, etc. by former General Electricity Utilities to revitalize the trading have been observed. As a final phase of the Electricity System Reform, legal separation of the power transmission sector and the power distribution sector of the former General Electricity Utilities is scheduled to be carried out by April 2020. Accordingly, some electric utilities are preparing for the separation of power transmission and distribution business as separate companies.

In Malaysia, the national utility, Tenaga Nasional Berhad (TNB) as at end of 2018 came up with an innovative package to provide billing, collection and remittance services to PV investors by including the billing of the PV investors in their monthly electricity bills. In doing so, counterparty risks due to customers not paying to the PV investors are reduced. Additionally, SARE provides deed of assignments to allow the payment collected from

ELECTRIC UTILITIES INVOLVEMENT IN PV / CONTINUED

customers to be channelled to financial institutions that financed the PV investors' projects. In return, TNB charges a small fee for the services provided under the SARE. Under the SARE, TNB, the PV investor and the customer entered into a tripartite agreement and with TNB on board, the project is attractive to the financial institutions as the PPA is bankable and this is helpful for the small medium enterprises/industries.

China continues to deepen its power system reform. In electricity market trading in 2018, the market-oriented power trading accounted for more than 30% of the total national volume, and eight power spot trading markets were established. In the first half of 2019, eight spot trading markets will start trial operation.

In March 2019, the National Energy Administration issued the "Pilot Work on Further Promoting the Construction of Power Spot Market (Draft for Comment), which reflected the policy orientation. The Exposure Draft proposed to establish a spot trading mechanism to promote clean energy consumption. In the initial stage of the spot market operation, clean energy can be used to participate in the spot market transactions by means of put forward volume without quotation, priority is given to clean energy as a price recipient to clearing out and achieve priority consumption.

In Canada, given the diversity in market structures, the interest from electricity utility businesses is equally variable. In general, many utilities offer lease-to-own programs.

The USA have a diverse deregulated utility landscape in which roughly 68% of consumers are served by an investor owned utility and the remaining customers are served by municipal utilities or cooperatives. Utilities are regulated at the local, state, and federal level by PUCs, ratepayer groups and federal agencies such as the Federal Energy Regulatory Commission (FERC) to ensure they provide fair and reliable service to their customers. Transmission is regulated by Independent System Operators (ISO) or Regional Transmission Organizations, depending on region.

Electricity utility interest in solar continues to increase in the United States. As utility scale solar has become increasingly competitive with retail generation, four broad categories of utility solar business models have emerged in the United States: utility ownership of assets, utility financing of assets, development of customer programs, and utility purchase of solar output

In Australia, the businesses that make up the electricity industry have collectively recognised the inevitability of solar power rolling out across Australia, and most have opted to play a constructive role.

Solar is impacting the energy market operation both technically and financially. 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 inverter response to system disturbance and impacts upon local voltages. 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.

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. Many newly created companies have succeeded in developing impressive renewable energy portfolios over the years. Thereby, renewable energy and most particularly PV are reshuffling the distribution between historical and emerging actors.

eight

LATEST TRENDS AND RESEARCHDEVELOPMENTS IN THE IEA PVPS TASKS

TASK 12: STATUS OF C-SI PV RECYCLING IN SELECT WORLD REGIONS

EUROPE

Europe is the only continent with dedicated c-Si PV recycling facilities operating commercially, as of early 2019. (Cadmium telluride (CdTe) thin film PV modules have been recycled at commercial scale for over 10 years, reaching nearly 4,500 t in 2017 (First Solar, 2018).) The largest facility, in France, currently can mechanically process 1,300 t/yr, with planned expansion to 4,000 t/yr in 2022 (Veolia, 2018). Another PV-dedicated recycling facility is under development in Germany and is expected to use pyrolysis with a combination of mechanical and electrochemical processes to achieve 90% total mass recovery, including trace metals (Suez, 2018). Its announced scale is approximately 137 modules/day. Both facilities received funding for process development from the European Commission. Meanwhile, statistics about EoL modules are being collected and reported in several countries (Table 1). Most PV modules recycled in Europe today are run in batches through existing glass or metal recycling lines (Wambach et al., 2017).

JAPAN

Twenty-three companies have been listed as accepting and "properly treating" PV modules in Japan (JPEA, 2019). However, only one of these companies specializes in recycling PV modules, though its process is limited to detaching the frames and separating front glass from the back sheet (see Box 2 for a description of typical PV module components); it has processed approximately 32,500 modules through February 2019 (PVTechnoCycle, 2019; NPC Incorporated, 2019). The other companies are intermediate processors of more common kinds of industrial waste (e-waste, cars, etc.) whose main function is to separate bulk materials and send them to more specialized recyclers (e.g., of metals, glass). Almost all these companies use a mechanical approach such as shredding and sorting and do not use specialized equipment for PV modules. Currently, silicon is not a target for recovery because of low value in the Japanese market. The Japanese government estimates that 4,400 t/yr of PV

TABLE 8.1: COLLECTION OF EOL PV MODULES FROM SELECTED EUROPEAN COUNTRIES (T)

	2015	2016	2017	2018	SOURCE
Germany	0	765	553		Stiftung EAR (2019)
United Kingdom	95	99	107	87	UK Environment Agency (2019)
France	0	0	84		ADEME (2018)

SOURCE IEA PVPS 8 OTHERS.

waste are generated currently (Japanese Ministry of Environment, 2018), which is projected to rise to 170,000–280,000 t/yr by the middle 2030s (METI, 2019).

UNITED STATES OF AMERICA

Currently, the USA lacks recyclers, policies, incentives, and regulatory drivers specific to PV recycling at state (except for Washington (Washington State Legislature, 2017)) and national scales. Voluntary efforts have emerged to fill the gap. The Solar Energy Industry Association's (SEIA's) National PV Recycling Program (SEIA, 2019) lists six US firms capable of recycling modules and inverters; five will accept c-Si modules, and one recycles its own thin-film modules. The more active c-Si recyclers in SEIA's program report receiving and processing a total of approximately 100 t per month (SEIA, 2019). (CdTe PV module recycling, by contrast, has been performed at commercial scale for more than 10 years, reaching 4,050 t recycled in 2017 (First Solar, 2018).) Owing to the low volumes of modules being sent for recycling, recycling lines dedicated to c-Si PV modules have not been developed in the US; c-Si module recycling now occurs on existing glass, metal, or e-waste product lines, in batches when a sufficient module volume is obtained by the recycler (EPRI, 2018b; Wambach et al. 2017). Existing recyclers seek specific materials that are best tied to current business models, flows, and capital assets. Consequently, recovery of materials by the recyclers listed in SEIA's program focuses on materials that can be separated and sold without extensive processing, like glass and bulk metal; unwanted materials are moved to other recyclers (Butler, 2019).

An empirical estimate of total US EoL PV modules is unavailable, but recycled modules likely represent only a small fraction. Based on anecdotal reports, some modules are being disposed of in municipal (nonhazardous) and hazardous landfills. Others are being stored until lower-cost and easier recycling options develop, accumulated quantities become more economical to ship and recycle, and issues such as testing for hazardous waste determination (toxic contaminant leach testing)—which affect interstate transport and treatment options and costs—are resolved (EPRI 2018b; California Product Stewardship Council, 2019).

TASK 13: CALCULATION OF PERFORMANCE LOSS RATES

The calculation of the evolution of a PV system performance is crucial to i) evaluate if a system is operating within the boundaries of long-term yield assessment and warranties and ii) provide more accurate values to be used in yield assessments not only in terms of absolute value but also in terms of uncertainty. In order to be able to judge a system performance, the performance loss (PL) must be calculated in an accurate and well documented way and uncertainty provided. Data availability, accuracy and resolution have to be taken into account when choosing and carrying out the necessary steps to calculate PL values. The calculation of PL in PV systems is not trivial as the "true" value remains unknown. Several methodologies have been proposed, however there is no consensus and thus a standardized approach to the calculation.

Within the IEA PVPS Task 13, a group of experts representing several leading R&D centers, universities and industry companies, is developing a framework for the calculation of Performance Loss Rates (PLR) on a large number of commercial and research PV power plants and related weather data coming from various climatic zones. Various methodologies are applied for the calculation of PLR, which are benchmarked in terms of uncertainties and "true" values. The aim of the international collaboration is to show how to calculate the PLR on high quality (high time resolution, reliable data, irradiance, yield, etc.) and on low quality data (low time resolution, only energy data available). Various algorithms and models, along with different time averaging and filtering criteria, can be applied for the calculation of PLR each of which can have an impact on the results. The approach considers three pathways to ensure broad collaboration and increase the statistical relevance of the study: i) use of shared methodologies on shared time series, ii) use of confidential methodologies on shared time series, iii) use of shared methodologies on confidential time series. The data is used for benchmarking activities and to define which methodologies clusters around a "true value" of PLR. The combination of metrics (PR or power based) and methodologies are benchmarked in terms of deviation from the average value and in terms of standard deviation. The combination of temperature corrected PR with the use of Year on Year or STL performs very well compared to others.

Another set of data is represented by the IEA PVPS Task 13 "PV Performance Database" which includes more than 120 PV plants from different climates. These data are considered of low quality as there is no confirmed quality check and the time resolution of energy and insolation is monthly; nominal power and the type of solarimeter is also given by external users. Two methodologies were applied, Seasonal and Trend decomposition using Loess (STL) and Year on Year (YoY), and the PLRs were analyzed in terms of PV technology and climate. STL results in an averaged PLR over all systems of -0.78%/a, while YoY yields -0.63%/a. STL is better suited if the time series data are of higher resolution and high-quality weather data are available.

Additionally, PL values of the datasets were divided into different technologies and Köppen-Geiger climate zones. As expected, thin-film systems experienced by far the highest PL of almost -1%/year in average. Both, mono- and poly-crystalline silicon systems were subject to lower losses of -0.5 to -0.7%/year, values which are additionally confirmed compared to previous studies. It was also visible that the climatic conditions affect the PL over time. High temperatures seem to have an especially severe effect. Comparing similar climate zones, which differ from one another mainly in humidity, did not suggest a proportional relationship between degradation and increasing humidity. Further studies in this regard must be carried out to confirm this hypothesis, also including climate zones in extreme humid conditions.

One important outcome of this study is the contribution to a clear and structured quality classification for PV time series data and a guideline for PLR calculations in dependency of the data categorization.

TASK 14: SOLAR PV IN A FUTURE 100% RES BASED POWER SYSTEM

Following the massive deployment of PV and other variable renewable energy sources (RES) – particularly wind – "high penetration" of Solar PV is no longer a local "distribution grid" issue that is limited to few regions or countries. Instead, we are increasingly seeing "RES dominated" grids, where variable generation from RES reaches levels in the order of magnitude of the load even at the transmission system level. This substantial transition of the power systems in numerous countries and regions brings a number of new technical as well as non-technical challenges. Starting with efficient solutions for the integration of power generation embedded in local distribution grids, interaction and sharing ancillary service provision between distribution and transmission system and finally managing wide-scale interconnected power systems with a large supply from variable sources. With Solar PV becoming the least-cost option for bulk power supply in more and more regions of the world, the integration into the power systems and their management will be the key to ensure an appropriate role and enable further deployment.

The following trends highlight the developments in 2018:

- **From Solar PV in the Distribution Grids towards 100% RES Supplied Power Systems**

  With increasing share of power supply coming from the distribution system, also the provision of ancillary services from the distribution to the transmission systems and more widely the interaction between the (mostly unbundled) operators of the two systems becomes vital to enable an efficient operation of the power system. Today it has become clear that Solar PV related integration questions, particularly related to system-wide issues have to be addressed together with other variable renewable energy sources. As part of the collaboration between IEA PVPS Task 14 and IEA WIND Task 25 ("Design and Operation of Power Systems with Large Amounts of Wind Power") a joint "Expert Group Report on Recommended Practice for Wind/PV Integration Studies" addressed these aspects and presented a best practice for performing Solar PV and Wind grid integration studies.

- **New Grid Code Requirements Maintain Stability and Increasing Resilience in Power Systems**

  The increasing share of static converter-based generation (PV and Wind) and a simultaneous decline of system inertia today provided almost exclusively by synchronous rotating generators, has further increased concerns about overall system stability and a general change in system behaviour during critical situations.

  In Europe, this fact has led to the establishment of European-wide "Network Codes", covering different aspects of the interconnected European electricity system. For Solar PV, the Network Code on Requirements for Generators, already led to a significant development in the national interconnection codes. These new requirements for all generators which started to be implemented in April 2019, aim to ensure system stability with increasing share of variable generation and market driven power flows.

  In the USA, the IEEE 1547 standard, defining the main requirements for the interconnection of distributed generators has been published in 2018, following a fundamental revision of its scope and approach. The new definitions now introduce comprehensive requirements for ride-through capabilities, grid support functions as well as communication and control features to be provided by all new distributed generators, not limited to Solar PV or Wind.

- **The Smart Grid is Becoming Reality**

  While still at the beginning, implementation of Smart Grid concepts in power systems worldwide are becoming a widespread option to address challenges of managing power systems, especially balancing load and demand with an increasingly decentralised supply and new components being connected to the more and more constrained grids, such as storage systems, flexible customers, intelligent buildings or electric vehicles. For Solar PV, a future Smart Grid can enable a wide range of additional services, provision of flexibility, enable local supply as well as the delivery of ancillary services. However, there are numerous questions to be answered to ensure a sustainable role for PV in this changing environment. Individual technologies for smart grid solutions are already available today. Now these technologies have to be more widely integrated into distribution grids, systematically linked together, and optimised.

  Task 14 has been supporting different stakeholders from research, manufacturing as well as electricity industry and utilities by providing access to comprehensive international studies and experiences with a dedicated focus on technical issues related to the role of Solar PV in a future 100% RES based power system.

TASK 15: ENABLING FRAMEWORK FOR THE ACCELERATION OF BIPV

The major cost decreases seen along the PV value chain in the last decade also benefitted building-integrated PV products. Consequently, the economic attractiveness of these solutions increased, allowing them to be competitive in multiple countries and under various configurations, as recently demonstrated in the frame of a European research project. Nevertheless, many cases continue to be relatively unattractive, from an economic point of view. Moreover, the BIPV market remains a niche market, both when considering its share of the PV market or the construction and building market.

It is extremely difficult to estimate the size of this BIPV market, in all regions of the world. Indeed, few countries specifically track BIPV installations. In most cases, related are shredded in generic distributed PV statistics. Nonetheless, today's BIPV market is at a turning point. While Europe, together with Japan, has historically been the main market for BIPV, the situation is changing rapidly. The technology has been gaining momentum in the USA for a few

TASK 15: ENABLING FRAMEWORK FOR THE ACCELERATION OF BIPV / CONTINUED

years now. In China, the industry is evolving very fast and many projects have been built, while more are announced. This could be soon become the number one market in installed capacity.

In most cases, also in the new markets, the developed projects are "flagship" projects. It means that the products are often tailor-made, and the economic viability of the project is not a crucial constraint. This limits their replicability, and the possibility to tap into more mainstream application, which would allow BIPV to become a mass market.

To reach such goals and activate the full potential of this technology, multiple obstacles remain to be overcome. The awareness and knowledge of experts from the construction and building sector, such as architects, are among the most crucial ones. Indeed, the technology is now quite mature, but still struggles to be adopted as a mainstream solution by these historical stakeholders. BIPV is perceived as an expensive product which adds a layer of complexity and constraints, for limited benefits. Various tools to easily integrated BIPV in project development processes are now available, but their adoption can be burdensome, which is deterring. Among the other obstacles, one can also mention the above-average initial investment cost, when compared to competing building envelope solutions. The lack of standards and the regulatory discrepancies between countries, for example between Member States if the European Union, in terms of PV regulation and building codes, also prevent the manufacturers and installers to easily expand and reach the necessary economies of scale and scope. Finally, the lack of business models capturing the full value of BIPV systems, which is itself depending on multiple elements, can also be pointed out as a limiting factor.

Regarding the drivers of the BIPV market, the already mentioned PV components' cost decrease can of course be highlighted. The increasing performances of PV systems also contributes to reinforcing the competitiveness of BIPV. The availability of customization options, such as different shapes, patterns and colours, reachable with a limited additional cost and limited performances' losses compared to "standard" solutions, is another key driver of the development of BIPV. In addition, the rising pressure put by policymakers to promote distributed renewable energy and to improve the energy performance of buildings are clear opportunities for BIPV.

On the industry side, manufacturers often have difficulties to reach a sufficient sales' level. Curiosity is high, but few prospects materialize. In most projects, the customer acquisition cost is considerable. Preliminary discussions and work going before even setting the deal up are energy and time-consuming. At the same time, one of the key issues of BIPV manufacturers is to find balance between the plant size required to enable economies of scale, while maintaining the necessary level of flexibility, allowing to respond to customers' requirements. Furthermore, this manufacturing flexibility is also crucial to be able to adapt the product to the local building codes, if required. This imperative has been well understood by the sector and constitutes one of the hot topics discussed among industry and research actors. Various equipment providers, in partnership with product manufacturers, have started developing tailor-made production tools. These are today available on the market, or soon will be. Researchers are also investigating price reductions of BIPV modules and systems' components, among others through technical innovations, an increasing flexibility of manufacturing processes, enhanced collaboration among stakeholders from the PV and the construction sectors, as well as optimized design and installation procedures. The possibilities to adapt colours and patterns of the BIPV modules without impacting cost and conversion efficiency is also a topic of attention, as it is considered as a means to increase the interest for BIPV solutions.

To conclude, building-integrated PV is now a quite mature technology, which reached economic competitiveness under many configurations, but still faces multiple challenges in order to convince more than "early adopters" to invest and enlarge its customer base.

TASK 16: STATE OF THE ART FOR SOLAR RESOURCE ASSESSMENTS AND FORECASTS

Task 16 deals with historical solar resource data as well as forecasting for the next few days. Since the Task 16 started (mid 2017) no new reports about those topics have been published. However, the precursor Task 46 (of IEA SHC) and also IEA PVPS Task 14 published reports about state-of-the-art methods. Common guidelines are given in the solar resource handbook – the main output of Task 46.[7] This report will be updated by end of 2020 the by Task 16.

SOLAR RESOURCE ASSESSMENTS

The amount of work needed for resource assessments depend on the size of the PV installation. Less uncertainty lowers financial uncertainty and therefore costs. The more money is involved the more the uncertainty of resource data plays a role. However, there are limits to know: even in best cases with 20 years of solar radiation measurements uncertainties of less than 2% are almost impossible to achieve. Additionally, climate change and decadal variation of climate induce variabilities that are almost impossible to foresee.

For small to medium sized systems the use of monthly averages of the last 10-20 years or typical meteorological years are common. Often such data are directly included in PV simulation tools. Global radiation on horizontal and plane of array are needed. For bigger projects (approx. > 100 MW) time series of satellite data or ground data (if available nearby – which is seldom) are used. For projects above 500 MW involving important financial investments often local measurements for one year (with high quality equipment and regular calibration and maintenance) combined with long term satellite data are

7 https://www.nrel.gov/docs/fy08osti/43156.pdf

common. For the adaptation of the local short-term measurements to the long-term data different methods exists – the team of Task 16 currently is writing a paper about this topic. Methods include linear regressions and quantile mapping of distributions. In order to better serve the results (to be published 2020 in a peer-reviewed journal paper), no clear winning method will be shown.

Additional meteorological parameters are also important. For small scale projects, at least the temperature is needed. For bigger projects precipitation, humidity, wind, albedo, soiling and snow conditions should be known.

SOLAR FORECASTS

The method to be used for solar forecasts depends on the time horizon of the forecasts. In the range of minutes either persistence (the radiation is taken as constant), stochastic models or all sky cameras are used. The uncertainties of those cameras are highly uncertain – the reason Task 16 is currently undertaking a benchmark (chapter 1.3).

For the time horizon of half an hour to four hours forecasts based on satellite images are standard. Several consecutive images are analysed, and cloud vectors detected (if not taken from forecast models). Those vectors are used to forecast the clouds and solar radiation in future. For a time horizon larger than six hours, numerical weather prediction models are best. As cloud position can't be forecasted exactly – the atmosphere is a chaotic system – probabilistic forecasts or at least combinations of different models are adequate. Post-corrections of forecasts are also needed as most prediction models show biased results.

Optimized forecast systems include a mixture of all three-time horizons.

BENCHMARK OF ALL SKY IMAGERS

All sky imagers (ASI) (also called cloud or sky cameras) are used for solar radiation forecasts for quite a few years now. Global radiation as well as direct radiation is forecasted for the upcoming 10-15 minutes in spatially and temporally high resolution. The development is in an early stage and most systems are developed in universities. There are only a few commercial systems available and many different methods to calculate the forecasts.

It's currently not possible to compare the uncertainty of the forecasts of the systems as individual validations have been made at different locations and different time periods – both extremely important regarding the accuracy.

In the framework of IEA PVPS Task 16, a first benchmark has been made. During four months (August – November 2019), six different camera systems have been run in parallel at the Plateforme Solar de Almeria (PSA).

The results will help users to know the methods of ASI forecasts, knowing state of the art and getting an idea of the general uncertainties. Results will be published beginning in spring 2020.

TASK 17: PV FOR TRANSPORT

In order to reduce greenhouse gas emissions from cars, initiatives aiming at a rapid rollout of electric vehicles (EV) and plug-in hybrid vehicles (PHV) have begun in countries across the world. However, unless clean power derived from renewable energy sources can be supplied, such vehicles will have a limited effect in reducing greenhouse gas emissions.

In response to this situation, PV-powered vehicles, especially PV-powered passenger cars are gaining attention as possible applications. Recently, various activities and projects on PV-powered passenger cars are implemented in the world.

The installation of PV on automobiles was originally proposed in the 1980s and early 1990s. At that time, use was limited to interior air conditioning and charging of electrical equipment. After Ford announced a concept car that uses PV as an energy source in January 2014, other car manufacturers began to investigate the potential of PV as a power source for driving an electric vehicle.[8]

Toyota Motor Corporation launched a plug-in hybrid vehicle equipped with a 180Wp crystalline Si PV panel as a power source in 2016. Projects into developing a PV-powered vehicle that uses PV as a main power source have begun in various countries around the world, with the twin aims of creating a new market for PV systems and of developing next-generation vehicles.

In Europe, Sono Motors of Germany has announced passenger cars with PV mounted on all surfaces of the vehicle,[9] while in the Netherlands, Lightyear has prepared PV-powered passenger cars for distribution in 2021.[10] Both PV-powered passenger cars will employ crystalline Si PV cells and the capacity will be over 1kWp. Also, Fraunhofer ISE, Germany, presented coloured solar car roof at the Frankfurt Motor Show (IAA) in September 2019.[11] The roof can be coated in any colour, with the PV cells with a nominal power of about 210 W/m². Although not the solar car exclusively powered by PV, it is expected the driving range can be extended by about 10 percent.

In Japan, NEDO, Sharp Corporation (Sharp), and Toyota Motor Corporation (Toyota) announced on the 4th July 2019, a plan to commence public road trials starting in late July 2019.[12] The trials aim to assess the effectiveness of improvements in cruising range and fuel efficiency of electrified vehicles equipped with high-efficiency PV. To facilitate the execution of this trial, Sharp modularized their world-class, high-efficiency PV cells (PV cell conversion efficiency of more than 34%). Toyota installed this panel on "Prius PHV" and was able to achieve a rated power generation output of around 860 Wp.

Additionally, China and South Korea are also developing PV-powered vehicles and companies have announced concepts.

8 Araki and Yamaguchi "Review of Recent Progress in Car-Roof PVs for Applications as an Automobile Energy Source", OYO BUTURI Vol. 88, No. 2, 2019

9 Sono Motors website (https://sonomotors.com/en/sion/)

10 Lightyear website (https://lightyear.one/)

11 Fraunhofer ISE website (https://www.ise.fraunhofer.de/en/press-media/press-releases/2019/fraunhofer-ise-presents-colored-solar-car-roof-at-the-frankfurt-motor-show-iaa.html)

12 NEDO website (https://www.nedo.go.jp/english/news/AA5en_100408.html)

CONCLUSION

In 2018, at least 103,2 GW of new PV capacity have been installed worldwide, almost as much as the 2017 installation level. Revised PV market data show every year some increase due to updated statistics in different countries, 2017 updated numbers pushed the installations above the 103,6 GW mark, reaching 409,1 GW in total. The stabilization of the market in 2018 hides anyway some major developments on all continents, which are continuing in 2019: PV develops fast thanks to its improved competitiveness and more efficient policies for distributed PV applications. However, the decline of the Chinese PV market in 2018, driven by the willingness to control the booming market and the necessity to contain the rise of electricity prices, hide completely the global growth.

This trend is visible in 2019 as well, while the growth is global, a declining level of installations in the largest market might again lead to a reduced global growth. Distributed PV represented a bit more than one third of all PV installations, while utility-scale continued to dominate the installations. Floating PV passed the GW of cumulative capacity for the first time, while agri-PV develops, especially in Asia. BIPV continued developing at a low pace while the first VIPV systems integrated in EVs are expected soon.

Policies evolved towards more competitive tenders for utility-scale PV but also for distributed installations. Feed-in tariffs were still dominant but decreasing while net-metering was still being implemented in new countries and phased-out in favor of self-consumption in others. Collective and decentralized self-consumption policies are being tested or cautiously implemented in new countries while merchant PV was gaining ground in few markets. In a nutshell, distributed PV was still hampered by difficulties to set-up adequate policies in dozens of emerging markets.

At the same time, production capacities increased in all segments of the PV value chain, mostly in Asia but not only. Such increase led to a new imbalance, which from June 2018 pushed the prices of all components low and reduced the margins, increasing again the competitiveness of PV solutions.

Monocrystalline wafers and cells started to dominate the market again in 2018, while bifaciality is being rolled-out. In general, modules and cells technologies are bringing an increased variety of end-products to the market: different back-sheets, glass-glass modules, half-cells and shingling are bringing more opportunities. Cell technology saw some MWT and HJT developments, while CdTe has experienced a major market push in 2018 and 2019.

Battery storage has continued to develop in support for utility-scale PV and in a limited number of countries for small-scale PV.

With more than 512,3 GW installed at the end of the year 2018, PV could provide almost 3% of the global electricity demand. Much more would be needed to decarbonize the energy sector and fulfil the COP21 agreement. While some countries start to take PV seriously, most haven't yet considered the full potential of an energy source which went below 0,02 USD per kWh in the most competitive tenders.

PV capacities at the end of 2018 save every year close to 600 Mtons of CO_2eq emissions, which represents a reduction of 4,5% of the power sector emissions. A higher percentage compared to the energy share because PV is massively installed in countries having highly carbon intensive grid mixes, like China and India.

As a conclusion, the fast development of PV is still too dependent on a limited number of countries but in general, the current growth path appears more sustainable than what it used to be. The PV era is just about to start.

ANNEXES

ANNEX 1: AVERAGE 2018 EXCHANGE RATES

COUNTRY	CURRENCY CODE	EXCHANGE RATE (1 USD =)
AUSTRALIA	AUD	1,340
EUROZONE	EUR	0,848
CANADA	CAD	1,297
CHINA	CNY	6,620
DENMARK	DKK	6,319
ISRAEL	ILS	3,596
JAPAN	JPY	110,424
KOREA	KRW	1100,587
MALAYSIA	MYR	4,1847
MEXICO	MXN	19,227
NORWAY	NOK	8,143
SWEDEN	SEK	8,703
SWITZERLAND	CHF	0,979
THAILAND	THB	32,32
TURKEY	TRY	4,849
UNITED STATES	USD	1

SOURCE IRS.

ANNEXES / CONTINUED

ANNEX 2: CUMULATIVE INSTALLED PV CAPACITY (MW) FROM 1992 TO 2018

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	2018
AUSTRALIA	7	9	11	13	16	18	21	23	26	30	35	41	47	55	64	74	104	189	578	1 444	2 491	3 283	4 131	5 057	5 908	7 178	10 953
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	1 098	1 271	1 440
BELGIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	110	667	1 096	2 164	2 890	3 154	3 266	3 388	3 590	3 903	4 337
CANADA	1	1	2	2	3	3	4	6	7	9	10	12	14	17	20	26	33	95	282	559	797	1 211	1 843	2 519	2 665	2 934	3 095
CHILE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	10	221	586	1 137	1 774	2 370
CHINA	0	0	0	0	0	0	0	0	11	16	34	44	54	62	72	92	132	292	792	3 492	7 052	17 732	28 372	43 522	78 072	131 140	175 400
DENMARK	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3	4	7	17	408	563	606	779	850	900	991
FINLAND	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	3	5	7	9	9	9	9	21	38	81	134
FRANCE	2	2	2	3	4	6	8	9	11	14	17	21	24	26	38	76	180	371	1 209	2 973	4 093	4 747	5 701	6 605	7 201	8 099	8 961
GERMANY	3	4	6	7	10	16	22	30	89	207	324	435	1 105	2 056	2 899	4 170	6 120	10 566	18 006	25 916	34 077	36 710	37 900	39 224	40 716	42 492	45 452
ISRAEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	22	67	186	272	377	588	771	877	952	1 358
ITALY	8	12	14	16	16	17	18	18	19	20	22	26	31	37	50	100	496	1 277	3 605	13 141	16 796	18 198	18 607	18 915	19 283	19 682	20 107,2
JAPAN	19	24	31	43	60	91	133	209	330	453	637	860	1 132	1 422	1 708	1 919	2 144	2 627	3 618	4 914	6 632	13 599	23 339	34 151	42 040	49 500	56 162
KOREA	0	0	0	0	0	0	0	0	0	0	5	6	9	14	36	81	357	524	651	730	1 025	1 556	2 482	3 616	4 503	5 834	8 099
MALAYSIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	4	34	136	196	247	314	357	860
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	311	485	4 103
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	0	0	0
NETHERLANDS	0	0	0	0	1	1	1	5	9	16	22	40	43	45	48	49	53	64	85	144	282	645	1 002	1 521	2 130	2 898	4 409
NORWAY	0	0	0	0	0	0	0	6	6	6	6	7	7	7	8	8	8	8	8	9	9	10	12	14	26	44	67
PORTUGAL	0	0	0	0	0	0	0	0	0	0	0	2	2	2	4	15	62	110	134	175	244	299	416	454	520	585	673
SOUTH AFRICA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	311	1 392	1 486	2 280	2 349	2 409
SPAIN	0	0	1	1	1	1	1	2	2	2	4	4	12	28	138	701	3 690	3 739	4 225	4 688	5 018	5 104	5 127	5 181	5 236	5 371	5 659
SWEDEN	1	1	1	2	2	2	2	3	3	3	3	4	4	4	5	6	8	9	11	15	23	42	77	126	205	268	426
SWITZERLAND	5	6	7	7	8	10	11	13	15	18	19	21	23	27	30	36	48	74	111	211	437	756	1 061	1 394	1 664	1 906	2 177
THAILAND	0	0	0	0	0	0	0	0	0	0	0	0	0	24	30	32	33	43	49	243	387	823	1 298	1 419	2 446	3 056	3 436
TURKEY	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	6	32	64	358	1 175	4 206	7 149
USA	0	0	0	0	0	0	0	0	0	0	0	0	111	190	295	455	753	1 188	2 017	3 937	7 130	12 076	18 321	25 821	40 973	51 818	62 498
TOTAL IEA PVPS	46	60	84	103	131	177	234	338	543	808	1 156	1 540	2 659	4 063	5 495	7 920	14 394	21 955	36 689	65 200	90 437	122 123	156 997	198 358	265 255	349 080	432 721
TOTAL NON IEA PVPS	0	0	0	0	0	0	0	0	1	2	4	17	29	33	38	49	135	774	3 075	5 656	10 404	16 044	21 169	29 984	40 259	59 988	79 572
TOTAL	46	60	84	103	131	177	234	338	544	810	1 160	1 557	2 688	4 096	5 533	7 968	14 529	22 729	39 763	70 856	100 841	138 166	178 166	228 342	305 514	409 068	512 294

SOURCE IEA PVPS 8 OTHERS.

ANNEX 3: ANNUAL INSTALLED PV CAPACITY (MW) FROM 1992 TO 2018

	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	2018
AUSTRALIA	7	2	2	2	3	3	3	2	3	4	5	6	6	8	9	11	30	85	389	866	1047	792	848	926	851	1270	3 775
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	169
BELGIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	86	557	429	1 068	726	264	112	122	202	313	434
CANADA	1	0	0	0	1	1	1	1	1	2	1	2	2	3	4	5	7	62	187	277	238	414	633	675	146	269	161
CHILE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	7	211	365	551	637	596
CHINA	0	0	0	0	0	0	0	0	11	5	19	10	10	8	10	20	40	160	500	2 700	3 560	10 680	10 640	15 150	34 550	53 068	44 260
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	50	91
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	53
FRANCE	2	0	0	1	2	2	2	2	2	3	3	4	3	2	12	38	104	191	838	1 764	1 120	654	954	903	596	898	862
GERMANY	3	1	1	1	4	6	5	8	59	117	117	111	670	951	843	1 271	1 950	4 446	7 440	7 910	8 160	2 633	1 190	1 324	1 492	1 776	2 960
ISRAEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	21	45	119	86	105	211	183	106	75	406
ITALY	8	4	2	2	0	1	1	1	1	1	2	4	5	7	13	50	396	781	2 328	9 536	3 655	1 402	409	308	368	399	425
JAPAN	19	5	7	12	16	32	42	75	122	123	184	223	272	290	287	210	225	483	991	1 296	1 718	6 968	9 740	10 811	7 890	7 460	6 662
KOREA	0	0	0	0	0	0	0	0	0	0	5	1	3	5	22	45	276	167	127	79	295	531	926	1 134	887	1 332	2 265
MALAYSIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	30	102	61	51	67	43	503
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	65	174	3 617
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	0	0	0
NETHERLANDS	0	0	0	0	0	0	0	4	3	8	6	18	4	2	2	1	4	11	21	59	138	363	357	519	609	768	1 511
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	18	23
PORTUGAL	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	11	47	48	24	41	69	55	117	38	66	65	88
SOUTH AFRICA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	305	1 081	94	794	69	60
SPAIN	0	0	1	0	0	0	0	1	0	0	2	0	8	15	110	563	2 989	49	486	463	330	86	23	54	55	135	288
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	63	158
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	271
THAILAND	0	0	0	0	0	0	0	0	0	0	0	0	0	24	7	2	1	10	6	194	144	436	475	121	1 027	610	380
TURKEY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	26	32	294	818	3 031	2 943
USA	0	0	0	0	0	0	0	0	0	0	0	0	111	79	105	160	298	435	829	1920	3 193	4 946	6 245	7 500	15 152	10 845	10 680
TOTAL IEA PVPS	46	14	24	19	28	47	57	103	206	265	348	384	1118	1404	1 432	2 425	6 474	7 561	14 734	28 512	25 237	31 686	34 875	41 361	66 897	83 824	83 642
TOTAL NON IEA PVPS	0	0	0	0	0	0	0	0	1	1	1	13	13	4	5	10	86	639	2301	2 581	4 748	5 640	5 125	8 815	10 275	19 729	19 584
TOTAL	46	14	24	19	28	47	57	103	207	266	349	397	1 131	1 409	1 437	2 435	6 560	8 200	17 034	31 093	29 985	37 325	40 000	50 175	77 172	103 554	103 226

SOURCE IEA PVPS 8 OTHERS.

LIST OF FIGURES & TABLES

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