JRC SCIENCE FOR POLICY REPORT

PV Status Report 2019

Jäger-Waldau, A.

2019

EUR 29938 EN

Contact information

Name: Arnulf JÄGER-WALDAU
Address: European Commission, Joint Research Centre, via Enrico Fermi 2749, 21027 Ispra (VA), Italy
Email: Arnulf.JAEGER-WALDAU@ec.europa.eu
Tel.: +39 033278-9119

JRC Science Hub
https://ec.europa.eu/jrc

JRC118058

EUR 29938 EN

PDF	ISBN 978-92-76-12608-9	ISSN 1831-9424	doi:10.2760/326629
Print	ISBN 978-92-76-12607-2	ISSN 1018-5593	doi:10.2760/329862

Luxembourg: Publications Office of the European Union, 2019

How to cite this report: Jäger-Waldau, A., *PV Status Report 2019*, EUR 29938 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-12608-9, doi:10.2760/326629, JRC118058.

Title PV Status Report 2019

Photovoltaics is a solar-power technology for generating electricity using semiconductor devices known as solar cells. A number of solar cells form a solar 'module' or 'panel', which can then be combined to form solar power systems, ranging from a few watts of electricity output to multi-megawatt power stations.

Growth in the solar photovoltaic sector has been robust. The Compound Annual Growth Rate over the last decade was over 40 %, thus making photovoltaics one of the fastest growing industries at present. The PV Status Report provides comprehensive and relevant information on this dynamic sector for the interested public, as well as decision-makers in policy and industry.

Contents

Foreword

The necessity to limit the maximum global average temperature rise to as close as possible to 1.5°C was acknowledged with the Paris Agreement. This agreement went into force on 4th November 2016. However, the current policies in place to limit global greenhouse gas (GHG) emissions are still insufficient to keep the temperature increase below 2°C. The burning of fossil fuels for energy purposes is still the largest source of the world's greenhouse gas emissions, accounting for 68%. Therefore, the decarbonisation of our energy system is the single most important component to achieve the target.

The G20 Ministerial Meeting on Energy Transitions and Global Environment for Sustainable Growth took place in Karuizawa, Japan on 15 and 16 June 2019. For the first time, Energy and Environment Ministers from the G20 countries gathered in joint sessions to address energy transition and global environmental challenges. Ministers focused on energy security, economic efficiency, environment and safety

The IEA's Energy Technology perspectives 2017 presented a pathway for achieving the goals of the Paris Agreement. In order to reach this, the power sector has to be fully decarbonised not by 2060 as modelled for a 2°C scenario, but well before 2050.

Photovoltaics (PV) is a key technology option for realising a decarbonised power sector and sustainable energy supply. Further it can be deployed in a modular way almost everywhere on the planet. Solar resources in Europe and across the world are abundant and cannot be monopolised by one country. Regardless of how fast energy prices increase in the future, and the reasons behind these increases, PV and other renewable energies are the only ones offering the stabilisation of, or even a reduction in future prices.

Between the end of 2009 and the first half of 2019, the benchmark Levelised Cost of Electricity from PV system decreased by 80% to USD 57/MWh (EUR 52/MWh). The main contribution was the decrease of module prices by over 85 % in most markets. Due to the continuous decrease of PV system prices and increasing electricity prices, the number of such markets is steadily increasing. In 2018, solar energy attracted 42.5 % of all new renewable energy investments which equates to USD 140 billion (EUR 122 billion).

In 2018, PV industry production increased by 5 % and reached a worldwide production volume of about 113 GW of PV modules. For 2019 a growth above 15% is forecasted. The compound annual growth rate (CAGR) over the last 15 years was above 40 %, which makes PV one of the fastest growing industries at present.

The 17th edition of the PV Status Report gives an overview of current trends. Over the last one and a half decades, the PV industry has grown from a small group of companies and key players into a global business where information gathering is becoming increasingly complex. This report seeks to bring together all available information. As it is a living document any additional information would be most welcome and will be used to update the report.

Ispra, November 2019

Piotr Szymanski

Director

Joint Research Centre, European Commission

Directorate C: Energy, Transport and Climate

Acknowledgements

Over the last two decades, in addition to the numerous discussions I have had with international colleagues, as well as literature and internet research, I have visited various government entities, research centres and leading industry companies in Australia, Chile, China, India, Japan, Singapore, South Africa, the United States and Europe. I would like to thank all my hosts for their kindness and the time taken to welcome me, to share their knowledge and to discuss the status and prospects of PV.

Executive Summary

For the 9th year in a row, solar power attracted the largest share of new investments in renewable energies, followed by wind power. The USD 140 billion (EUR 122 billion) investments in solar energy, accounted for 42.5 % of all new renewable energy investments. While the annual investment decreased by 13%, the newly installed capacity of solar photovoltaic power increased by about 5% to over 107 GW in 2018.

Over the last 15 years, the production volume of solar PV has increased with a compound annual growth rate (CAGR) of over 40 %, which makes the industry one of the fastest growing ones in the world. Until 2006, the solar cell production was dominated by Japan and Europe. After the rapid increase of the annual production in China and Taiwan since 2006, a new trend emerged in 2014 to rapidly increase production capacities in other Asian countries such as India, Malaysia, Thailand, the Philippines or Vietnam.

Market development for solar PV systems did not follow the production at the same pace, which led to overcapacities and massive price pressure along the production value chain. This development triggered a consolidation of the manufacturing industry, which is still ongoing.

R&D spending for renewable energies increased by 10% to reach USD 13 billion (EUR 11.3 billion). About half of this R&D went to solar energy. However despite the urgent need for a rapid decarbonisation of our energy supply this is still only 10.7% of the total R&D spending of USD 121 billion (EUR 105 billion) for energy.

The trend that the developing economies invest more in renewable energy capacity than the developed ones continued for the fourth year.

The PV industry has changed dramatically over the last few years. China has become the major manufacturing country for solar cells and modules, followed by Taiwan and Malaysia.

According to market forecasts, the installed PV power capacity of 520 GW at the end of 2018 could reach up to 1.4 TW by 2024. At the end of 2019, worldwide solar PV power is expected to reach 650 GW capable of producing roughly 4 % of the worldwide electricity demand. The EU's share is about one fifth of the world-wide installed capacity and can provide about 5.5 % of its electricity demand.

Recent 100% renewable electricity scenarios have highlighted the importance of solar photovoltaics to achieve this goal and decarbonise the power sector in a cost effective manner. To realise a carbon free power supply by 2050, the installed PV generation capacity of about 650 GW at the end of 2019 has to increase to more than 4 TW by 2025 and 21.9 TW by 2050. This indicates that the installation rate has to increase by a factor of 2.5 until 2025. The European Union needs to increase its capacity from 117 GW at the end of 2018 to more than 630 GW by 2025 and 1.94 TW by 2050. In case of a transition to a sustainable transport sector, i.e. electrification and synthetic fuels, these numbers would need to increase by a factor of two.

2016 already saw a number of record breaking power purchase agreements (PPA) contracts and bids below USD 30/MWh and the trend for bids below 25 USD/MWh has accelerated in sun rich regions in 2017 and 2018. The trend continued in 2019 with offers below USD 20/MWh. These very low bids and PPAs are only possible through a combination of excellent solar resource, high debt shares and very low debt costs as well as the fact that some tariffs are indexed to inflation.

PV is a key technology option for implementing the shift to a decarbonised energy supply and can be deployed in a modular way almost everywhere on this planet. Over the last decades the growth of PV energy use was mainly driven by public incentives, but the shift now to economics driven use of solar PV electricity as one of the lowest cost electricity supplies is obvious.

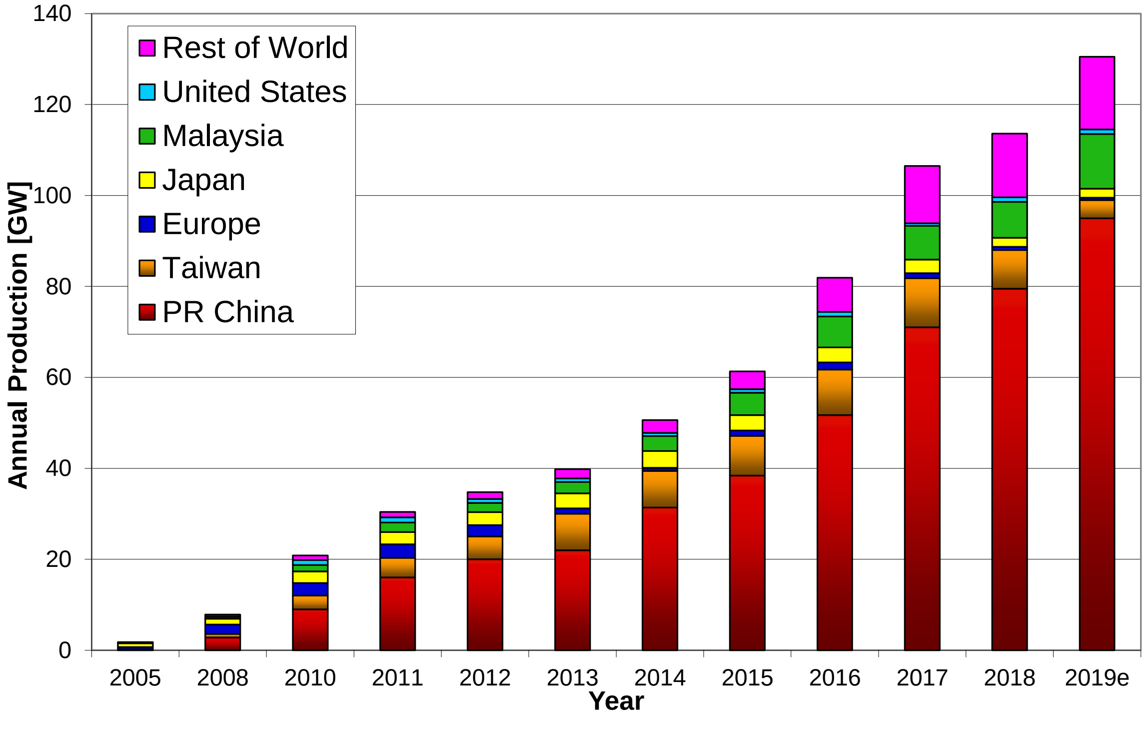
1 Introduction

Reported production data for the global solar cell production[1] in 2018 vary between 110 GW[2] and 120 GW and estimates for 2019 are in the 120 to 140 GW range. The significant uncertainty in these data is due to the highly competitive market environment, as well as the fact that some companies report production figures, while others report sales and again others report shipment figures.

The data presented, collected from stock market reports of listed companies, market reports and international colleagues, were compared to various data sources and thus led to an estimate of 114 GW (Fig. 1), representing an increase of about 5 % compared to 2017 and another 10% are expected for 2019.

Since 2000, the production of solar photovoltaic devices has grown with a CAGR of over 40 %. After the rapid increase of the annual production in China and Taiwan since 2006 a new trend emerged in 2014 to increase production capacities in other Asian countries like India, Malaysia, Thailand, the Philippines or Vietnam. It is interesting to note that most of these investments are done by Chinese companies. Another trend in the PV industry was the rapid increase in original equipment manufacturing (OEM) volumes since 2011, which allowed larger companies to significantly increase their shipment volumes without adding new capacity of their own.

Figure 1: World PV cell/module production from 2005 to 2019 (estimate)



Total investment in the energy sector was USD 1.85 trillion in 2018 [IEA 2019]. Power sector investments accounted for USD 775 billion or 42%. Investments in renewable power was leading with USD 304 billion, followed by the network infrastructure with USD 293 billion, fossil-fuel power plants with USD 127 billion, nuclear with USD 47 billion and battery storage with USD 4 billion. Including the USD 25 billion investment in renewable energy for transport and heat a total of USD 329 billion was invested in renewable energy sources compared to USD 806 billion investments for the coal, gas and oil supply. To-

[1] Solar cell production mean:
- In the case of wafer silicon based solar cells, only the cells
- In the case of thin-films, the complete integrated module
- Only those companies which actually produce the active circuit (solar cell) are counted
- Companies which purchase these circuits and make solar modules are not counted

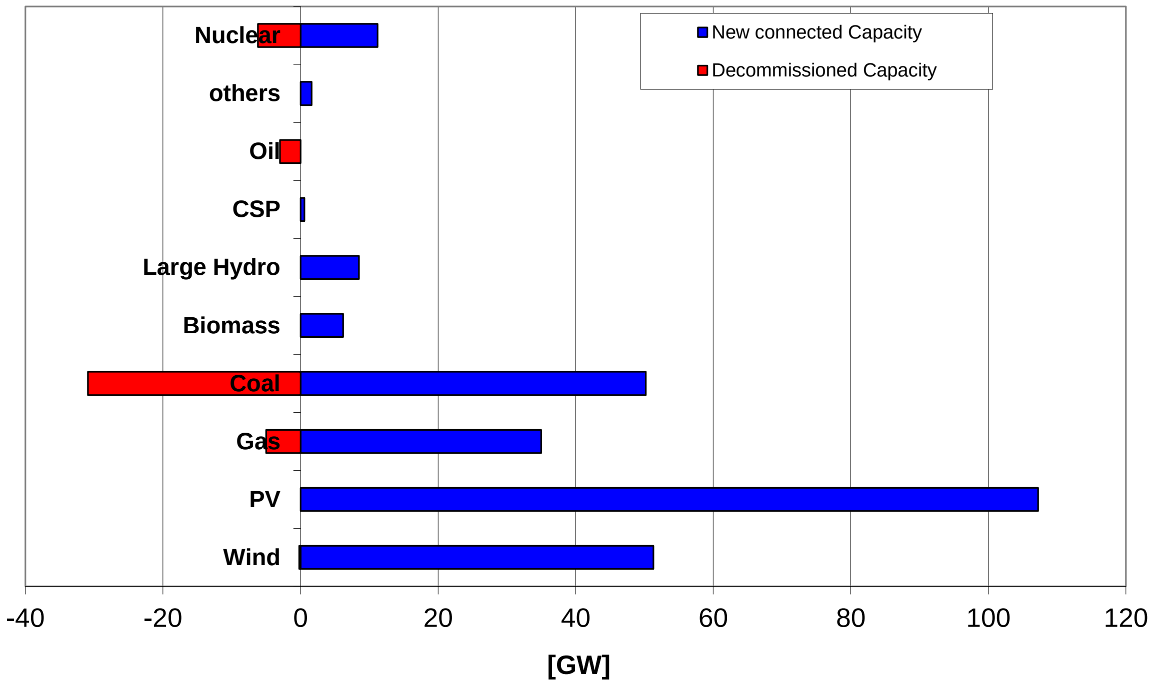
[2] Please note that all number are based on the current available data (October 2019) and can change, when final annual reports of public companies or country statistics are published later

tal new installed renewable power capacity, excluding large hydro, increased from 158 GW in 2017 to 190 GW in 2018.

Uncertainties in production statistics
• Only a limited number of companies report production figures for solar cells or thin film modules. • Shipment figures can include products from stock, already produced in the previous year. • Some companies report shipments of 'solar products' without a differentiation between wafers, cells or modules. • The increasing trend towards Original Equipment Manufacturing (OEM) increases the risk of double counts.

World-wide, a total of about 272 GW of new power generation capacity were connected to the grid year and 45 GW were decommissioned, resulting in 237 GW of new net capacity (Fig. 2) [Gwe 2019, IEA 2019, own analysis]. Renewable energy sources (RES) including large hydro accounted for 167 GW or 61 % of all new power generation capacity. PV electricity generation capacity accounted for 107 GW, or 39 % of the new installed capacity.

Figure 2: New connected or decommissioned electricity generation capacity world-wide in 2018



Source: [Gwe 2019, IEA 2019a] and own analysis

The share of electricity in the final consumption provided by renewable energy sources (excluding hydro) increased from 9.7% in 2017 to 10.8% in 2018 [IEA 2019a, Ene 2019]. In 2018, PV and wind electricity generation was up by 31% and 12% respectively compared to 2017. Including hydropower, the renewable electricity generation rose by 7% and accounted for 25.6% of total electricity production. However, power generation capacity expansion with renewable energy sources has to accelerate considerably, if the IEA Sustainable Development Scenario (SDS) of half the power coming from renewables in 2030 should be achieved.

Total power generation increased by 3.5% to 26 590 TWh in 2018. After three years of declining GHG emissions from the power sector, emissions increased 2.6% in 2017 and a further 2.5% in 2018. This is in contradiction with the SDS scenario, where emissions have to decrease on average 4.1% per year until 2030.

R&D trends for governmental and industrial spending for renewable energies were positive in 2018 [Ren 2019]. While government spending increased by 8% to USD 5.5 billion (EUR[3] 4.8 billion), corporate R&D increased even more by 12% to USD 7.5 billion (EUR 6.5 billion). However, compared with the total R%D spending for energy by governments (USD 26 billion) and industry (USD 95 billion) this is still a small fraction of the overall energy R&D expenditures [IEA 2019].

For the 9th year in a row, solar power attracted the largest share of new investments in renewable energies [Blo 2019]. The USD 140 billion (EUR 122 billion) investments in solar energy, accounted for 42.5 % of all new renewable energy investments. Despite a 22% annual investment decline, the newly installed capacity of solar photovoltaic power increased by 7% to about 107 GW in 2018. However, one has to keep in mind that a number of solar projects closed their financing earlier, but were only commissioned in 2018. In such cases the investment is counted for the year of the financial closure, while the capacity addition is counted for 2018.

The trend that the developing economies invest more in renewable energy capacity than the developed ones continued for the fourth year. Out of the USD 140 billion (EUR 122 billion) investments in solar energy, 54% or USD 75 billion (EUR 65 billion) were invested in developing economies.

In terms of investments into renewable power (excluding large hydro), China kept the lead with USD 91.2 billion (EUR 79.3 billion), followed by Europe USD 61.2 billion (EUR 53.2 billion), the USA with USD 48.5 billion (EUR 42.2 billion) and India USD 15.4 billion (EUR 13.4 billion).

Between 2008 and 2014, PV module prices have decreased rapidly by more than 80 %, then 2015 saw a short levelling out due to industry consolidation and increasing markets, mainly in China and Japan [Blo 2013, 2016]. However, since the beginning of 2016 module prices have again seen a sharp decrease in prices, which put all solar companies along the value chain under enormous pressure [Blo 2019a].

World-wide overcapacities along the PV value chain still exist and started to build up as a result of very ambitious investments beginning in 2005. The investments in solar cell and module manufacturing equipment, excluding polysilicon manufacturing plants, peaked in 2011 at about USD 14 billion (EUR[4] 10.8 billion) after the PV market grew by more than 150 % in 2010. However, in the following years, the market growth for solar photovoltaic systems slowed and was not able to absorb the output of this massive and rapid increased manufacturing capacity. The result was a huge oversupply, which led to continuous price pressure along the value chain and resulted in a reduction of market prices for polysilicon materials, solar wafers and cells, as well as solar modules. This development resulted in the insolvency of many companies. Consequently, equipment spending declined dramatically and hit the bottom with around USD 1.7 billion in 2013 before it started to rebound in 2014 [Sol 2014]. Early 2018 it was reported that PV CAPEX (from c-ingot to module) had surpassed USD 7 billion in 2017 and could reach USD 10 billion in 2018 [Col 2018].

Consolidation in the PV manufacturing industry has led to the closure or takeover of a significant number of companies since 2009. Despite those bankruptcies and companies with idling production lines or even permanent closures of their production facilities, the number of new entrants to the field, notably large semiconductor, construction or energy-related companies, is remarkable and makes a reasonable forecast for future capacity developments very speculative.

Nevertheless, the general trend still is pointing in the direction of more capacity announcements despite the existing excess capacity. However, it is important to recall that

---

3 Exchange rate 2018: EUR 1.00 = USD 1.15
4 Exchange rate 2013: EUR 1.00 = USD 1.30

the existing excess capacity is different in the four main parts of the silicon module value chain, i.e. (1) polysilicon production, (2) wafer production, (3) solar cell manufacturing, (4) module manufacturing. According to Bloomberg New Energy Finance (BNEF) the group of Tier 1 module manufacturers have a production capacity of 139 GW in in 3Q 2019 [Blo 2019a].

Despite the continuing problems of individual companies, the fundamental industry as a whole remains strong and the overall PV sector will continue to experience significant long-term growth. The IEA's Renewable Energy Market Report 2019 forecasts world-wide a new installed photovoltaic power capacity between 720 and 880 GW between 2019 and 2024 [IEA 2019b].

For 2019, the world market predictions vary between 95 GW according to Solar Power Europe's low scenario and 142 GW in the Q3 BNEF Global PV Market Outlook [Blo 2019a, Sol 2019]. The same sources predict a range between 94 GW and 152 GW in 2020.

The current solar cell technologies are well established and provide a reliable product, with a guaranteed energy output for at least 30 years.

This reliability, the increasing demand for electricity in emerging economies and possible interruptions due to grid overloads there, as well as the rise in electricity prices from conventional energy sources, all add to the attractiveness of PV systems.

About 95 % of current production uses wafer-based crystalline silicon technology. Projected silicon production capacities for 2019 vary between 524 000 tonnes [Blo 2019] and 703 000 tonnes [Ikk 2019]. It is estimated that about 30 000 tonnes will be used by the electronics industry. Potential solar cell production will, in addition, depend on the material used per Wp (grams per Watt-peak). The blended global average was about 3.5 g/Wp in Q3 2019. According to the International Technology Roadmap for Photovoltaic polysilicon material consumption is expected to drop to values between 2.1 and 2.6 g/W in 2029 [Itr 2018].

In general, global CAPEX for PV solar systems have converged, even if significant differences still exist due to differences in market size and local competition and factors like import taxes, local content rules or existing tax credits. In the 1st half year (H1) 2019, the BNEF global benchmark for levelised cost of electricity (LCOE) in the solar sector was given with USD 57 per MWh a decrease of about 18% compared to 2018 [Blo 2019b]. The cost share of solar modules in the benchmark PV system has dropped below 30 %.

The influence of CAPEX on LCOE of solar PV electricity has decreased significantly and other costs like O&M (operations and maintenance) costs, permits and administration, fees and levies as well as financing costs play a more dominant role. Therefore, these variable and soft costs must be targeted for further significant cost reductions.

In countries with a developed electricity grid infrastructure, the increasing shares of PV electricity in the grid lead to a growing importance of the economics of integration. Therefore, more and more attention is focused on issues such as:

- development of new business models for the collection, sale and distribution of PV electricity, e.g. development of bidding pools at electricity exchanges, virtual power plants with other renewable power producers, and storage capacities;
- adaptation of the regulatory and legal procedures to ensure fair and guaranteed access to the electricity grid and market.

The technical challenges are different ones in countries with a weak electricity grid or where not all citizens have access to electricity at all. The access to electricity and the design of new electricity infrastructure should be based no longer on the dependence of classical centralised power generation units, but use the new available technology options of decentralised renewable power generation sources like photovoltaics. The smart use of the locally available mix of different renewable energy sources as well as demand and supply side management has to be an integral part of every energy plan to avoid stranded investments in the future.

The cost of direct current (DC) electricity generated by a PV module has dropped below EUR 0.02/kWh in many places world-wide, although a significant additional cost component relates to transporting the electricity from the module to where and when it is needed. Therefore, new innovative and cost-effective electricity system solutions with PV as an integral part of sustainable energy solutions are needed now. The optimisation of solar PV electricity plant design and operation has direct effect on the O&M costs, which play an important role for the economics of the PV installation. With the continuous decrease of hardware CAPEX, the non-technical costs, linked to permit applications and regulations are representing an increasing share of the total costs and need to be reduced as well.

2 The PV Market

Annual new solar PV system installations increased from 29.5 GW in 2012 to 107 GW world-wide in 2018, driven by a shift to more large scale utility systems on the one hand and a worldwide reduction of PV system prices on the other side (Fig. 3). The annual installation in 2018 was about 5% higher than in 2017, increasing the world-wide PV power to almost 520 GW at the end of 2018.

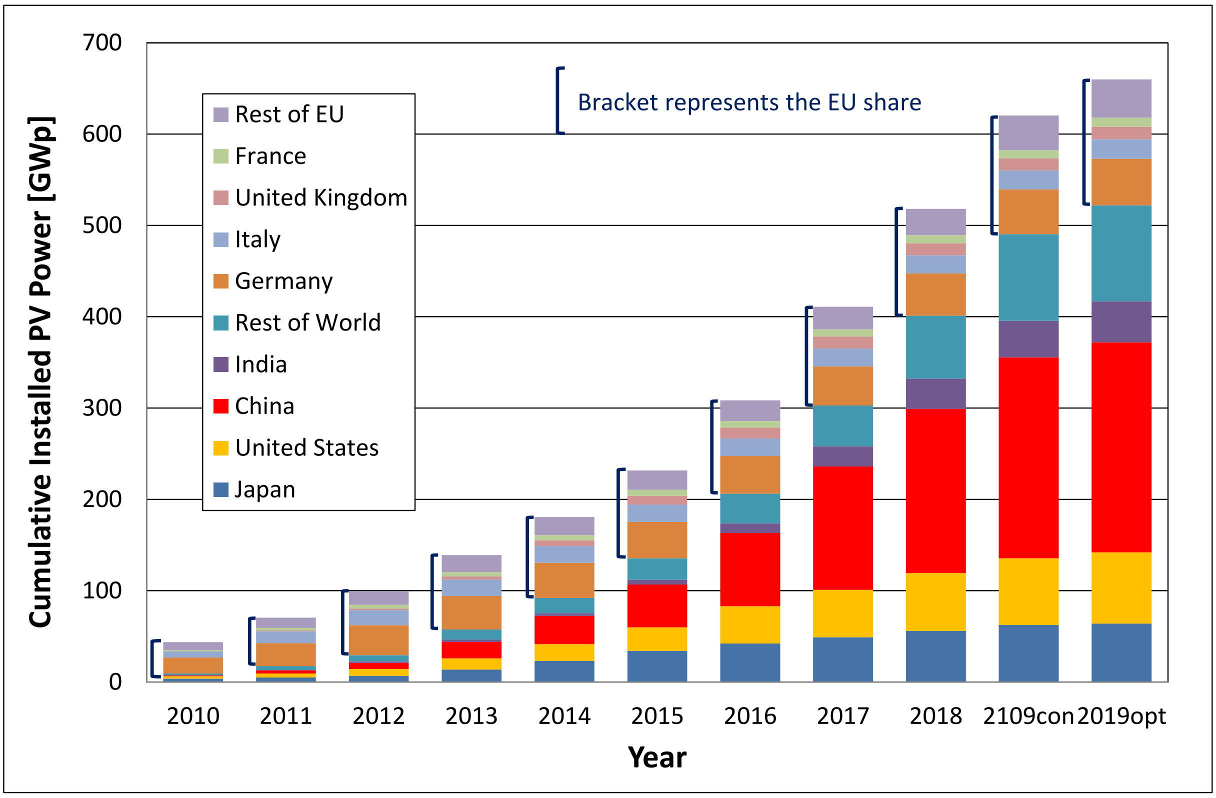
This development represents the grid connected PV market. To what extent the off-grid and consumer product markets are included is not clear, because these markets are very difficult to track. However, these segments have become smaller and smaller in relative terms.

Uncertainties in market statistics

- The installation figures of this report are about the physical installation of the system hardware, not the connection to the grid. The grid connection can be delayed due to administrative reasons or in some cases missing grid capacity.
- If not specifically indicated, this report uses nominal DC peak power (Wp) under standard test conditions (1 000 W irradiance, air mass 1.5 light spectrum and 25 ºC device temperature) for reasons of consistency.
- Not all countries and press releases report DC peak power (Wp) for solar PV systems. Especially for larger scale system the utility peak AC power is used, which is relevant for the transmission operator. Even in the Eurostat and IRENA statistics the two capacities are sometimes mixed.
- Some statistics only count the capacity which is actually connected or commissioned in the respective year for the annual statistics, irrespectively when it was actually installed. This can lead to short term differences in which year the installations are counted and the annual statistics, but levels out in the long-run, if no double counting occurs. E.g.:
  (1) in Italy about 3.5 GW of solar PV systems were reported under the second *conto energia* and installed in 2010, but only connected in 2011;
  (2) the construction period of some large solar farms spread over two or more years. Depending on the regulations – whether or not the installation can be connected to the grid in phases and whether or not it can be commissioned in phases, the capacity count is different.
- Some countries do not have official statistics on the capacity of solar PV system installations or sales statistics of the relevant components.

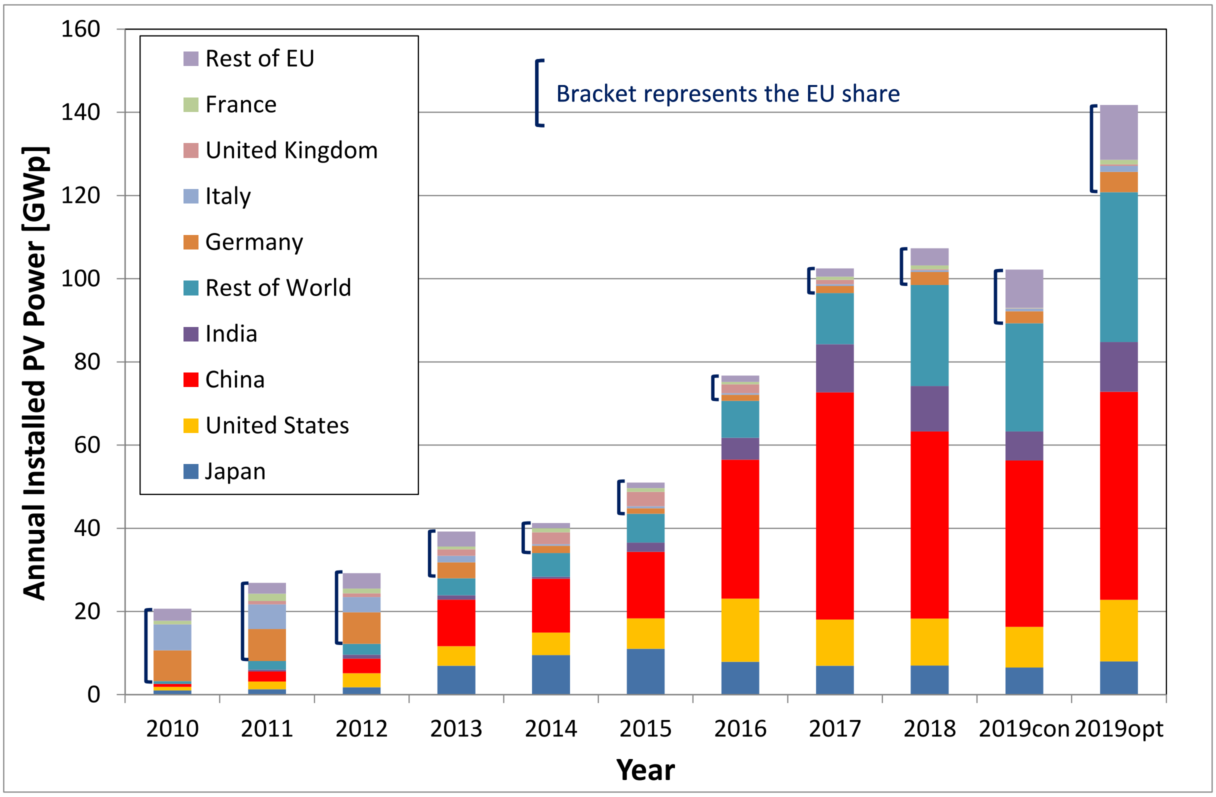
Since 2015, China is the country with the largest PV power capacity. In 2017, China also overtook the European Union in terms of total installed PV power capacity. With over 44 GW of new connected PV system capacity it reached a total PV power capacity of 175 GW or 34% of the 518 GW solar PV electric power capacity installed worldwide at the end of 2018. The European Union follows with a cumulative installed PV power of 117 GW or 23% of global capacity. This is down from the 66% share in 2012, when the cumulative installed solar PV electric power had just reached 100 GW world-wide.

Figure 3: Cumulative PV system installations from 2010 to 2019 estimates



Source: [IEA 2019b, Sol 2019, Sys 2019] and own analysis

Figure 4: Annual PV installations from 2010 to 2019 estimates



Source: [IEA 2019b, Sol 2019, Sys 20198] and own analysis

2.1 EUROPE, THE RUSSIAN FEDERATION AND TURKEY

Since the first European Renewable Energy Directive went into force in April 2009 grid-connected solar photovoltaic (PV) systems in the European Union have increased tenfold from 11.3 GW at the end of 2008 to over 117 GW at the end of 2018 [Jäg 2018].

Just before the COP meeting in Katowice in December 2018, the European Commission published its Vision for 2050, A Clean Planet for all, in which it was outlined that the use of renewable energy sources has to exceed 60% by 2050 to reach an average of 1.5ºC or net zero emissions [EC 2018].

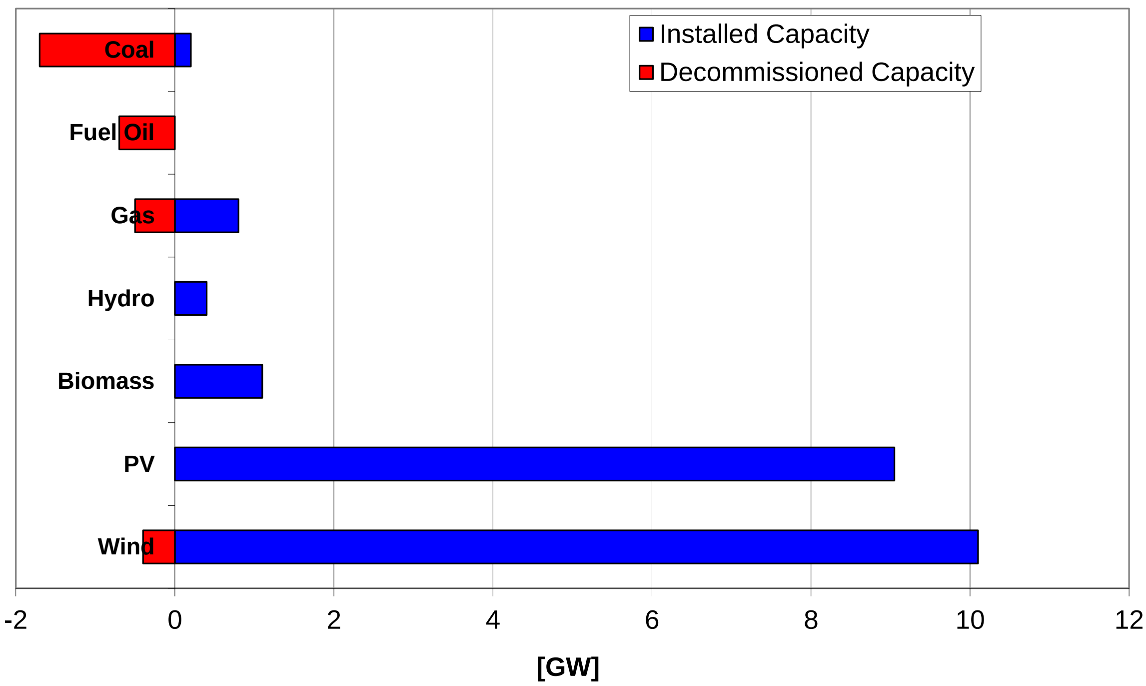
Already the 2016 European Commission (EC) initiative "New Deal for Energy Consumers: Empowering Consumers, Developing Demand Side Response; using smart technology; linking Wholesale and Retail Markets; Flanking Measures to Protect Vulnerable Customers" listed as one of the options the right to self-generate and consume self-produced electricity [EP 2016]. This right is now part of the new renewable energy directive, which was published on 21 December 2018 [EU 2018].

In the political guidelines for the next European Commission 2019 – 2024, the president elect Ursula von der Leyen, pledged on 16 July 2019, to present a green deal in her first 100 days in office [Ley 2019]. She outlined her ambition for a more rapid cut in GHG emissions and wants to reduce emissions by at least 50% in 2030. For 2021 it is planned to present a plan towards a 55% reduction target by 2030.

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 have a significant influence on the economic attractiveness of installing PV systems.

Looking at the electricity system as a whole, a total of about 21.7 GW of new power generation capacity were installed in the EU last year and 3.3 GW were decommissioned, resulting in 18.4 GW of new net capacity (Fig. 5) [Ago 2019, Sys 2019, Win 2019, own analysis]. Renewable energy sources (RES) accounted for 20.7 GW or 95.4 % of all new power generation capacity. PV electricity generation capacity accounted for 9 GW, or 42 % of the new installed capacity.

Figure 5: New connected or decommissioned electricity generation capacity in the EU in 2018

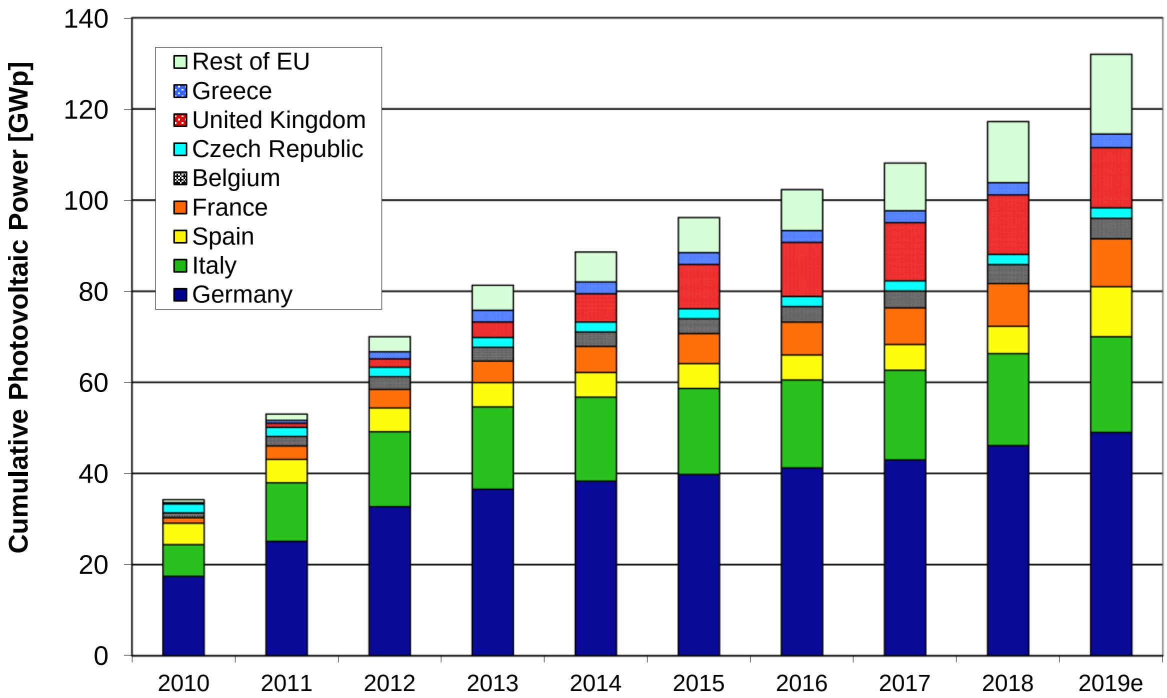


Source: [Ago 2019, Sys 2019, Win 2019] and own analysis

In terms of new net capacity, wind power was first with 9.7 GW, followed by solar PV 9 GW, biomass plants with 1.1 GW, hydro 0.4 GW and natural gas with 0.3 GW. The net installation capacity for coal- and oil-fired power plants was negative, with a decrease of 1.5 GW and 0.7 GW, respectively.

With a cumulative installed capacity of over 117 GW (Fig. 6), the EU has further lost ground in the worldwide market. The European Union accounted for 23% of the global total of 518 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 130 TWh of electricity or about 4.8 % of the final electricity demand in the Union.

Figure 6: Grid-connected PV capacity in EU

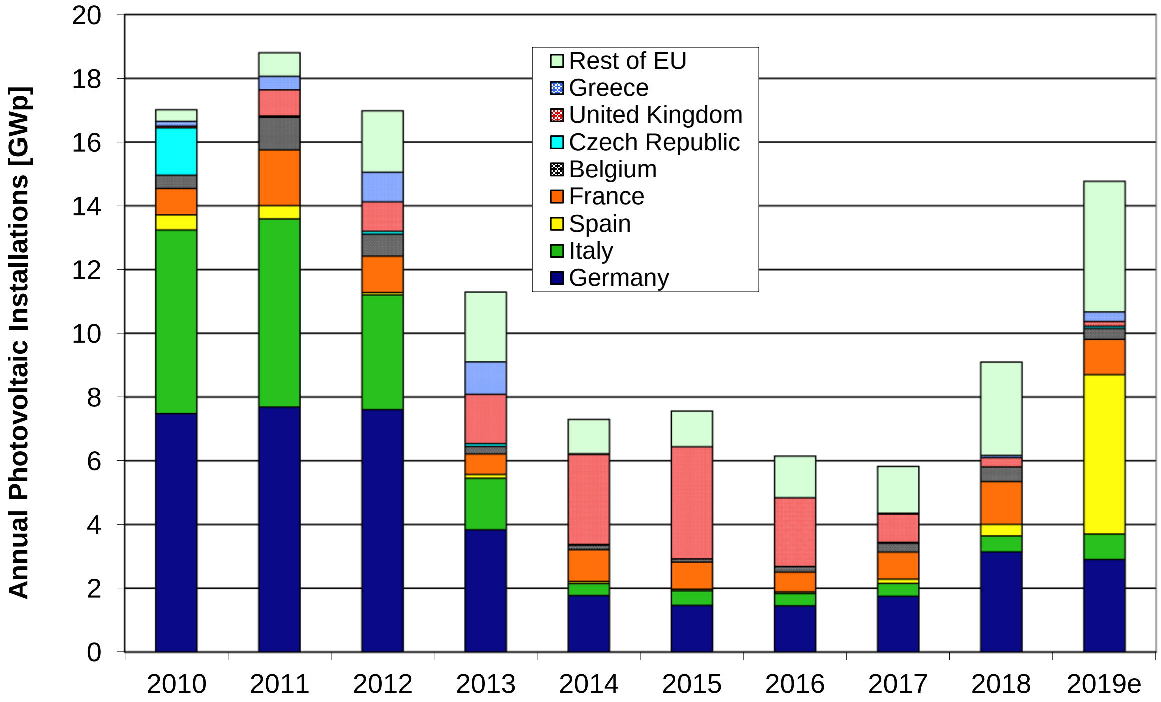


Source: [Sol 2019, Sys 2019] and own analysis

At first glance, this development looks like a success. However, analysing 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 (Fig. 7). After its peak in 2011, when PV installations in the EU accounted for 70% of worldwide installations, six years of market decreases and stagnation followed. This trend was finally reversed when the PV market in the European Union increased almost 50%, from about 6 GW in 2017 to about 9 GW in 2018. The increase was due to stronger than expected markets in Germany (3.1 GW), the Netherlands (1.4 GW), France (>1 GW), and Hungary (>0.5 GW).

After five years of very little new PV power additions in Spain, 2019 saw some change. In July 2017, the Spanish Ministry for Energy and Tourism [GoS 2017] announced the winners of the second renewable energy auction and solar photovoltaic power projects had won 3.9 GW_{AC} (~ 5 GW_{DC}) in this auction. The winning consortia have to connect the systems before the 1 of January 2020.

Figure 7: Annual PV installations in EU



Source: [Sol 2019, Sys 2019] and own analysis

An increase in Europe's ambition to reduce GHG emissions by 2030 requires more renewables for an accelerated carbon free electrification. A shift from fossil based electricity generation to non-combustible renewable electricity generation, i.e. hydro, solar and wind, will reduce the total primary energy demand (TPED) by a factor of two to three, thus increasing the overall energy efficiency.

The New Energy Outlook (NEO) 2018 by Bloomberg New Energy Finance forecasts a slight electricity demand increase in Europe (EU-28, Island, Norway and Switzerland) from 3 454 TWh in 2017 to 3 566 TWh in 2030. The increase is driven by the increased use of electric vehicles (EV) and partly compensated by progress in energy efficiency [Blo 2018b]. This is in line with the estimates for the European Union that the net electricity generation will be around 3 400 TWh in 2030.

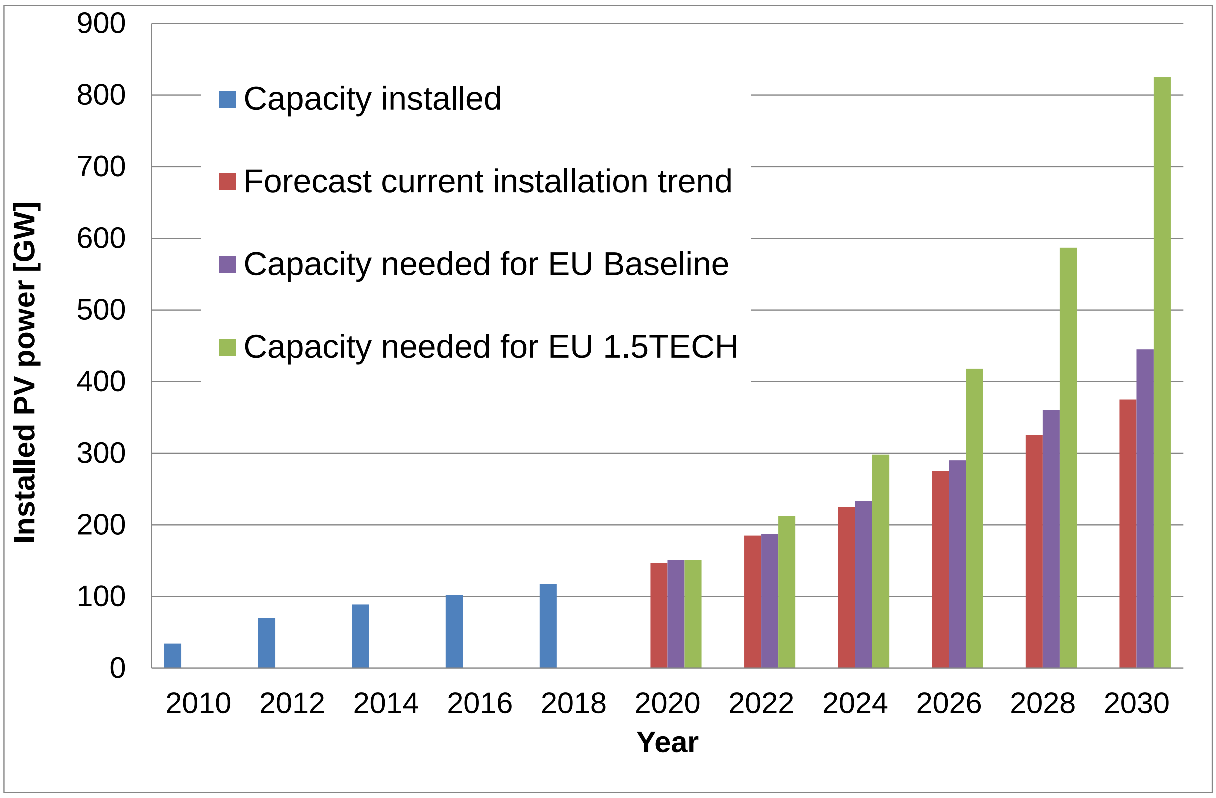
In order to achieve the 50 to 55% GHG reduction target pledged by Ms von der Leyen, what PV capacity would be needed until 2030? To answer this question, two scenarios from the analysis of the Commission Communication "A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy" were used [EC 2018a].

The first one is the baseline scenario, which should reach a GHG reduction of 65% by 2050. The cumulative solar capacity of this scenario would be 441 GW_{DC}. The second scenario is the 1.5TEC one, which would achieve a 57% reduction by 2035 with a GHG reduction of 80% in the power sector. To achieve this reduction in the power sector a PV capacity of 825 GW_{DC} would be needed. This is of course a simplified picture as all the different scenarios include a wide range of technology options and technology adaptation assumptions. However, solar photovoltaic electricity generation is one of the few technologies ready and scalable now. In Figure 8 it is shown how the installed PV capacity would have to develop to reach these capacities in 2030.

For 2019 new photovoltaic power capacity of 14 to 15 GW is expected in the European Union, increasing the total to about 130 GW by the end of the year. To reach the scenario targets a 14% CAGAR is needed for the baseline and 18.5% CAGAR for the 1.5TEC scenario. This corresponds to roughly a fourfold increase of the market between 2019 and 2030 in the baseline and an eightfold increase in the 1.5TEC scenario. More details can be found in a recent study [Jäg 2019a].

Figure 8 shows the actual and projected PV installations under the current market conditions and those installations needed to achieve the baseline or the 1.5TEC scenario. The current market conditions seem not sufficient to meet the targets.

Figure 8: Actual and projected photovoltaic installations from 2010 to 2030



The following sections describe market development in some EU Member States, as well as in Switzerland, the Russian Federation, Ukraine and Turkey. Not all EU Member States are covered in this report due to either small markets or limited changes in the market development.

2.1.1 Austria

In 2018, Austria installed about 170 MW of new PV systems and increased the cumulative capacity to 1.44 GW. The electricity generation from PV systems was 1.44 TWh or 2.4% of the national electricity production in 2018.

The Ökostrom-Einspeisetarifverordnung 2012 (Eco-Electricity Act) is the regulation that sets the prices for the purchase of electricity generated by green power plants. In addition, there is a federal investment subsidy programme for PV systems with different sizes. For each of these categories a limited budget is available. In 2019, the investment costs of PV systems below 100 kWp are supported with a maximum of EUR 250/kWp and EUR 200/kWp for systems between 100 and 500 KWp. Greenfield systems (on agricultural land) are not eligible. Storage systems can be supported with a maximum of EUR 500/kWh and up to a maximum of 10 kWh/kWp installed.

In addition to these federal programmes, five federal states have their own PV programmes and four states have programmes to support the installation of electricity storage.

In June 2017 the Eco-Electricity Act was changed. For 2018 and 2019 an additional budget of EUR 15 million each year to support PV systems and electricity storage was agreed [BGB 2017].

At the end of May 2018, the Austrian Government approved the new Climate and Energy Strategy – "mission 2030" – for Austria [GoA 2018]. The main issues concerning photovoltaics are:

- Increase the share of renewables in final energy consumption to 45-50% by 2030. This corresponds to about 80 TWh of electricity or 30 TWH more than today from hydro, solar and wind.
- In 2030 renewable electricity production should cover 100% of electricity consumption.
- Investment support programme for "100,000 rooftops with local storage".
- Removal of all taxation on self-generation, currently exempted up to 25 MWh.
- Change incentives to a combination of feed-in premiums, auctions and investment incentives.

According to a study by the Energy Economics Group of the Technical University of Vienna, the installed PV capacity to realise "mission 2030" should be in the range of 14 to 15 GW by 2030 , a more than 10-fold increase compared to 2017 [Haa 2017].

2.1.2 Belgium

The three Belgian regions (Brussels, Flanders and Wallonia) have individual support schemes for PV, but one electricity market. Therefore, some regulations are regional and others are national. A common denominator is the fact that all three regions selected an renewable portfolio standard (RPS) system with quotas for RES. A net-metering scheme exists for systems up to 5 kWp Brussels or 10 kWp (Flanders and Wallonia) as long as the electricity generated does not exceed the consumer's own electricity demand.

In 2011, Belgian installations peaked with over 1 GW of new systems, before starting to decline in 2012. At the end of 2018, cumulative installed capacity was over 4.25 GW with about 370 MW installed in that year. About 10 % of Belgian households are already generating their own PV electricity, and PV power supplied 3.6 TWh or 4.4 % of the country's net electricity production in 2018.

The proposal of the Belgium Parliament for a new Energy Pact 2050 was published in January 2018 [BKV 2018]. The main issues concerning photovoltaics are:

- Gradual phase-out of Belgium's 6 GW of nuclear capacity between 2022 and 2025 and increase of renewables in the power supply to 40% by 2030 (8 GW of PV, 4.2 GW onshore wind and 4 GW offshore wind).
- Increase of renewables in the power supply to 100% by 2050.
- 2 GW of large-scale storage and 3 GW of distributed small-scale storage.

The Belgian grid operator Elia published three scenarios for the Belgian electricity supply indicating that total PV power could be in the range of 5 to 11.6 GW by 2030 and in the highest scenario could go up to 18 GW by 2040 [Eli 2017]. To reach the 2030 targets of the Energy Pact, the present market size of about 370 MW only has to increase slightly over the next 12 years.

2.1.3 Denmark

In 2018 about 180 MW were installed increasing the total capacity to over 1.1 GW. PV systems generated 953 GWh or 2.8% of the Danish electricity in 2018.

At the end of November 2016, the German Bundesnetzagentur announced the results of the first cross boarder auction with Denmark: five bids, all of them from Denmark and to be built there, totalling 50 MW won at a price of 5.38 cents per kilowatt hour (EURct/kWh) [Bna 2016]. The results of the first Danish cross border auction in December 2016 revealed even lower prices. The 9 winning tenders will get a fixed premium of 12.89 Danish øre per kWh (EUR 17.32/MWh) for 20 years on top of the Danish spot market price, which is fluctuating in the range of EUR 30 to 40/MWh [Ene 2016].

In 2017, the Danish government decided to have a tender for PV systems smaller than 1 MW in 2018 and a joint tender for solar and wind power in 2018 and 2019 [Ene 2018a]. The support scheme was approved by the European Commission in August 2018 [EC 2018b]. In December 2018, the Danish Energy Agency announced the six winning bids of the 2018 technology neutral tender [Ene 2018b]. Three solar photovoltaic projects with a combined capacity of 104 MW and bids for tariff premiums between DKKøre 2.84 and 2.98 per kWh (EURct[5] 0.38 and 0.40 per kWh) were selected.

In February 2019, Better Energy announced the signature of a 125 MW commercial Power Purchase Agreement (PPA) in Denmark [Bet 2019]. The PV plant is scheduled to be operational in 2020.

2.1.4 France

In 2018, 873 MW of new PV systems were connected to the grid in France [Rte 2019]. Total cumulative connected capacity in mainland France and Corsica increased to over 8.5 GW. In addition, total capacity in the French Overseas Departments stood at about 390 MW [Sta 2019]. Electricity production (continental France and Corsica) from PV systems was 10.2 TWh or 2.1 % of the national electricity consumption [Rte 2019].

On 22 July 2015, France's National Assembly adopted the Energy Transition for Green Growth Act. The legislation aims to reduce France's reliance on nuclear to 50 % of power generation by 2025 and increase the share of renewable energies in the final gross energy consumption to 23 % in 2020 and 32 % in 2030 [MEE 2016].

The targets for PV to achieve the 2023 goal are 10.2 GW installed PV power by 2018 and between 18.2 and 20.2 GW by 2023. Under the new support mechanism, feed-in tariffs are only available for systems below 100 kW capacity and tenders for systems above. However, there is still a difference for the larger systems: Systems between 100 and 500 kW bid for fixed tariffs, larger systems for a market premium. In the first half of 2018 PV systems with a capacity of 479 MW were connected to the grid [Sta 2018]. The capacity of projects in the planning stage increased to 6 GW, of which 2.5 GW already had a signed connection agreement.

In 2016, the mandatory introduction of smart meters started and should be completed by 2021. This measure provides an indirect support measure for small self-consumption systems, because it removes the grid connection costs. These costs were in general more than 12% of the price of a 3 kW system.

2.1.5 Germany

Compared to 2017, new PV system installations in Germany saw an increase of almot 80% to 3.14 GW, with about 760 MW free-field systems as a result of previous auctions [Bun 2019]. About half of new PV systems are now being combined with electricity storage systems. For the first 8 months of 2019 the Bundesnetzagentur reported the registration of PV projects with 2.7 GW.

The German market growth is directly correlated to the introduction of the Renewable Energy Sources Act (Erneuerbare Energien Gesetz EEG) in 2000 [EEG 2000]. This law introduced a guaranteed feed-in tariff (FiT) for electricity generated from solar PV systems for 20 years and already had a fixed built-in annual reduction which was adjusted over time to reflect the rapid growth of the market and corresponding price cuts. However, the rapid market growth required additional adjustments. Until 2008, only estimates of installed capacity existed, so a plant registrar was introduced on 1 January 2009.

Since May 2012, the FiT has been adjusted on a monthly basis depending on the actual installation of the previous quarter. The revision of the EEG in 2014 changed the system size for new systems eligible for a feed in tariff and introduced levels of levies on self-consumption [EEG 2014]. So far systems with a capacity of less than 10 kWp are excepted form the levy. For all other systems, the levy on each self-consumed kWh increased to 40% on 1 January 2017.

Since 1 September 2015, owners of new ground mounted systems have to participate and win an auction of the Federal Network Agency. The total amount of capacities auctioned is determined by political decisions and limits this market segment.

Starting on 1 January 2016 only systems smaller than 100 kWp are eligible for a fixed feed in tariff and since then also larger rooftop systems have to market their electricity or

[5] Exchange rate: 1 EUR = 7.46 DKK

take part in auctions. The relevant feed-in-tariffs are regularly published by the Bundesnetzagentur.

The fact that the tariff for residential PV systems smaller than 10 kWp (October 2019: EUR 0.1018/kWh) is now well below the average variable electricity rate consumers are paying (EUR 0.267- 0.331/kWh) and the fact that they are still exempt from the EEG levy makes self-consumption attractive and opens up new possibilities for the introduction of local storage. Since July 2017 a programme to support self-consumptions for tenants of multi apartment buildings exists, but until September 2019 only about 435 PV systems with 9.5 MW cumulative power were installed [Bna 2019].

Between May 2013 and December 2018, the Kreditanstalt für Wiederaufbau (KfW) has been offering low interest loans to install storage for PV systems up to 30 kWp [KfW 2013, 2016].

2.1.6 Greece

In 2009, Greece introduced a FiT scheme which started slowly until the market accelerated from 2011 until 2013, when 425 MW, 930 MW and more than 1 GW of new PV system capacity was installed respectively. This boom ended on 10 May 2013, when the Greek Ministry of Environment, Energy and Climate Change (YPEKA) announced retroactive changes in the FiT for systems larger than 100 kWp and new tariffs for all systems from 1 June 2013. During the first five months of 2013 almost 900 MW were installed and increased the total cumulative capacity to over 2.5 GW. About 2.4 GW were installed in 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 [Adm 2019]. 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 [Hed 2019]. In total about 46 MW of new PV capacity was installed in 2018.

After the European Commission approved the new auction scheme on 4 January 2018 [EC 2018c], 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 July 2019 auction the average PV tender tariff was €0.06278/kWh, a solar electricity price 9.37% lower than the starting level of €0.06926/kWh.

2.1.7 Hungary

The Hungarian 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 phased out on 31 December 2016. However, all project owners, who had submitted their application before this deadline, were still eligible for this scheme.

In July 2017 the European Commission approved the new renewable support scheme (METÁR) [EC 2017]. For systems with a capacity below 500 kW a feed in tariff (FiT) and for systems between 500 kW and 1 MW a feed-in premium (FiP) will be set at the beginning of each year. The approved internal rate of return (IRR) used to calculate the level of the FiT and FiP and the duration of support is 6,94 %. Systems above 1 MW are eligible for a competitive FiP determined by a bidding procedure.

In the first half of 2018, METÁR, which finally came into force October 2017, already had some turbulences, when the government unexpectedly brought forward the application deadline for projects of 50 - 500kW to 26 April 2018, whereas in the original government decree no deadline was foreseen. No date for a bidding for larger systems has been set yet.

In 2018 Hungary connected about 410 MW of licensed PV systems and over 90 MW of residential PV systems, increasing the cumulative PV power to over 1 GW. The Hungarian Energy and Public Utility Regulator (MEKH) reported that the utility scale PV capacity had increased from 726 MW at the end of 2018 to over 1.1 GW at the end of June 2019. In the same time period, the residential PV capacity increased from 332 MW to 388 MW.

2.1.8 Italy

In 2018, Italy connected 440 MW of PV systems, increasing cumulative installed capacity to 20.1 GW according to the annual report of the Italian Ministry of Economic Development [MSE 2019]. After the Quinto Conto Energia (Fifth Energy Bill) ended in July 2013, the only support mechanisms are now via the Scambio sul Posto (self-consumption) scheme and a tax break for the system investment costs.

According to the Italian national grid operator TERNA, electricity from PV systems provided 22.9 TWh or 7.1 % of the total electricity sold in 2018 [Ter 2019]. Solar photovoltaic power generation was 12.55 TWh or 7.98 % of the total electricity during the first six months of 2019. The highest monthly coverage was in June 2019, when PV electricity supplied 10.6 % of the Italian energy demand.

In March 2018, ENEL announced that it started the production of bi-facial silicon modules at its 3SUN factory in Catania, Sicily, and aims to increase the production volume to 240 MW by 2019 [Ene 2018c]. In February 2019 the company processed the first heterojunction (HJT) cells with over 22% efficiency in the framework of the European funded AMPERE project [Amp 2019]. Commercial production of modules with this cell type started in August 2019.

2.1.9 The Netherlands

According to the Dutch Statistical Office, PV systems with a capacity of 1.5 GW were installed in 2018 bringing the total installed PV power to 4.4 GW at the end of the year [Cbs 2019]. The total generated solar electricity was 3.2 TWh or 2.7 % of the net electricity generation.

Since 2011, the main incentive has been a net-metering scheme for small residential systems up to 15 kW and a maximum of 5 000 kWh/year. Systems larger than 15 kW can apply for the programme to stimulate sustainable energy production (SED+), for a maximum of 950 full load hours per year, which is open for all renewable energy technologies [RVO 2019]. Over 5 100 PV projects with a combined capacity of 2.92 GW applied in the first round of the 2019 SDE+.

2.1.10 Poland

The Polish National Renewable Action Plan required by the EU Renewable Energy Directive (2009/28/EC) foresees to reach a renewable energy share of 15.5% in the gross final energy consumption. Renewable electricity should reach 19.13% of the final energy supply by 2020.

The Renewable Energy Act of 2015 went into force in July 2016 and replaces the previous green certificate system with an auction scheme [GoP 2016]. 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 [Ieo 2019]. A further auction with up to 700 MW capacity is foreseen in the second half of 2019.

In 2018, Poland connected about 235 MW of PV systems, increasing cumulative installed capacity to 500 GW [Ieo 2019]. 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.

On 23 July 2019, the Polish Government announced an investment support scheme "*Mój Prąd*" (My Electricity), for residential PV systems. Residential PV systems with a capacity between 2 kW and 10 kW can receive a support of a maximum of PLN 5 000 (EUR[6] 1 175) or 50% respectively. The total amount of this scheme is PLN 1 billion (EUR 235 million) sufficient to support at least 200 000 new PV systems until the end of 2020. Access to the support is on a first come first serve basis until the fund is depleted.

2.1.11 Spain

Spain takes the fifth place in Europe with regard to the total cumulative installed capacity, at 5.6 GW[7]. Most of this capacity was installed in 2008 when the country was the largest market, with over 3.3 GW [IEA 2014]. As a consequence, the Spanish Government started to introduce a number of regulations in order to limit the growth of the sector already in 2008 and suspended the remuneration pre-assignment procedures for new renewable energy power capacity in January 2012. The justification given for this move was that, until then, Spain's energy system had amassed a EUR 24-billion power-tariff deficit. The government argued that the special regime for renewable energy was the main reason for this. However, this argument was more than questionable as the deficit already amounted to almost EUR 9 billion in 2007, a time when payments under the special regime for renewable energy were still limited. After peaking in 2013 with EUR 28.8 billion the deficit had decreased to EUR 23 billion at the end of 2016 [CNM 2017]. According to press reports, Moody's estimates that the deficit will decrease by over 9% from the EUR 21 billion at the end of 2017 to about EUR 19 billion at the end of 2018 [Eur 2018].

A more detailed description of the development of the Spanish market can be found in earlier PV Status Reports [Jäg 2016].

In 2018, new PV systems were installed with a capacity of 262 MW_{AC}. The Spanish photovoltaic energy association (UNEF) estimates that electricity from PV systems for self-consumption, which are not counted by the official electricity statistic generated about 580 GWh in 2018. In the same year, electricity generated from grid connected PV systems contributed 7.78 TWh or 3 % of the Spanish electricity generation [Red 2019].

After five years of very little new PV power additions, the coming years will see significant solar capacity additions because of the national target to 100% renewable power sector by 2050. In July 2017, the Spanish Ministry for Energy and Tourism announced the winners of the second renewable energy auction in 2017 and solar photovoltaic power projects had won 3.9 GW_{AC} in this auction [MET 2017]. The winning consortia have to connect the systems before the 1st January 2020. Merchant projects, wherein there is no regulated income, represents another driver for the solar photovoltaic market.

2.1.12 Switzerland

In 2018, about 270 MW of PV systems were installed in Switzerland, increasing the total capacity to 2.2 GW [Bfe 2019]. In 2018, PV power generated 1.9 TWh or 3.4% of the Swiss electricity demand. Market expectations for 2019 are in the range of 300 to 350 MW.

After a 40 % price decrease in 2012, prices for turnkey systems fell by a further 12 % in 2013 and a further 5 % until 2015 [Ezs 2016]. In 2018, prices for installed and connected residential PV systems (< 10kWp) were in the range of was CHF 2.000 to 3.500 per kWp without value added tax (VAT). For larger rooftop systems above 100 kWp the price range was CHF 650 to 1.400 per kWp. In average a 5 to 10% price reduction could be observed in 2018.

In May 2017, the Swiss voted to increase the available amount for renewable energy support schemes from CHF 900 million (EUR[8] 780 million) to CHF 1.380 million (EUR

---

[6] Exchange rate: 1 EUR = 4.24 PLN

[7] This report gives installed DC capacities, whereas the Spanish installations were quoted as AC capacity in the past. Therefore, there is a difference between these and the numbers in the PV status reports before 2014.

[8] Exchange rate Q4 2017: EUR 1 = CHF 1.15

1.200 million) per year. In addition the new energy law prohibits the construction of new nuclear power plants and the existing ones are phased out at the end of their.

Switzerland has an "Energy Strategy", which aims to transform the energy system by 2050 and photovoltaics should play a key role in it. According to official scenarios, about 11.1 TWh of electricity should be generated by solar photovoltaic systems, roughly 6 times the 2018 values. On the other side, the Swiss Federal Office of Energy has published a PV rooftop potential of 50 TWh or 90% of the national energy demand in September 2018. There is an online tool for the potential evaluation of each roof and facade in Switzerland (www.toitsolaire.ch).

2.1.13 UK

Between 2011 and 2018 the solar photovoltaic electricity capacity increased from less than 100 MW to 13.1 GW at the end of 2018 [GUK 2019]. In 2018, PV systems generated 12.9 TWh or 3.8 % of the UK electricity generation. In the first six months of 2019 136 MW of new solar photovoltaic capacity was registered.

The old FiT scheme for systems up to 5 MW closed on 14 January 2016 and a new scheme opened on 8 February 2016, with different tariff rates and rules — including a limit on the number of installations supported in various capacity bands [GUK 2016]. The new scheme offers a 'Generation Tariff' for each generated kWh and in addition an 'Export Tariff' for up to 50 % of the generated electricity, which is not consumed on-site at the time of generation (self-consumption). Both tariffs are adjusted each quarter and depend in addition whether or not the respective band caps are reached.

Larger systems can participate in Contracts for Difference Allocation Rounds. In the first round, which was held in 2015 five projects with a total capacity of 72 MW won contracts with a strike price of 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.

2.1.14 Other European countries, Russia and Turkey

In **Croatia,** PV systems with a capacity up to 5 MW are eligible for a FiT. According to the Croatian Energy Market Operator (HROTE), 53.43 MW of PV systems were installed under this scheme at the end of May 2019 [Hro 2019]. Between 1 and 2 MW additional capacity was added in 2018. In April 2019, Hrvatska Elektroprivreda (HEP) announced to build four PV power plants with a combined capacity of 11.3 MW until April 2020 [Hep 2019]. 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 installed increasing the cumulative capacity to 673 MW [Dir 2019]. 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. 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 [DGE 2109]. The winning bids were between EUR 14.76/MWh and EUR 31.16/MWh. These projects have to be realised until the end of June 2022.

After two years of rapid growth (2010/2011), 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 [GoR 2016]. 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 to Hevel Solar and Fortum in an auction. Hevel Solar won three projects with close to 40 MW to be connected to the grid at the end of 2019, while Fortum won 7 projects with 110 MW to be operational by 2021 and 2022.

In March 2010, **Turkey**'s Energy Ministry unveiled the 2010-2014 Strategic Energy Plan. One of the government's priorities was to increase the ratio of renewable energy resources to 30 % of total energy generation by 2023. At the beginning of 2011, the Turkish Parliament passed renewable energy legislation which defined new guidelines for FiTs. The FiT was USD 0.133/kWh (EUR 0.10/kWh) for owners commissioning a PV system before the end of 2015. If 'made in Turkey' components are used, the tariff was increased by up to USD 0.067 (EUR 0.052), depending on the material mix. To take advantage of these local procurement rules, factories have been set up by Anel Enerji, Atsco Solar and China Sunergy to produce PV modules. The first licensing round for a volume of 600 MW, which closed in June 2013, was oversubscribed by about 15 times with close to 9 GW of projects submitted to the Turkish Energy Regulatory Authority. However, so far only about 82 MW were installed at the end of 2018.

Due to the fact that systems below 1 MW fall under the category of "non-licenced plants" the market started to take off in 2016. At the end of 2018 the cumulative capacity had exceeded 5.4 GW_{AC}, most of it in the category of "non-licenced" according to the Turkish transmission operator TEİAŞ [Tei 2019]. 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 MW_{DC} [TCR 2019]. However, only public installations used for agricultural irrigation, water treatment plants or waste treatment facilities are eligible as ground mounted projects. Market expectations for 2019 are between 1 and 1.5 GW.

In 2009, the **Ukraine** introduced the "Green Tariff" policy, a feed-in tariff scheme for electricity generated from renewable energy sources [Bvr 2009]. 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. The market expectations for 2019 are between 1 and 1.3 GW.

2.2 Asia and the Pacific region

Asia and the Pacific region again had the highest share of new installed PV power capacity in 2018. About 76 GW of new PV electricity generation systems were installed in the region, which corresponds to roughly 71% of the world wide new PV power installed in 2018. The largest market was China with 45 GW, followed by India with around 11 GW and Japan with about 7 GW. In 2019, a similar market size, but different country contributions is possible.

2.2.1 Australia

In 2018, about 4.1 GW of new solar PV electricity systems were installed in Australia, bringing the cumulative installed capacity of grid-connected PV systems to 11.6 GW. Different from previous years the utility scale market with 2.36 GW exceeded the residential market with 1.7 GW [Ega 2019]. In the first six months of 2019 PV systems with 1.8 GW have already been registered increasing the number of homes with PV systems to over 2.1 million. The national penetration of homes with PV systems has exceeded 20 %, and in some urban areas it is even more than 50 %.

The average PV system price paid by the customer for a grid-connected system fell from AUD 6/Wp (EUR[9] 4.29/Wp) in 2010 to AUD 1.03/Wp (EUR[10] 0.65/Wp), including the Small-scale Technology Certificate discount (STC) in August 2019 [Sol 2019a]. The STCs are a mechanism of the Small-Scale Renewable Energy Scheme (SRES) to support residents and businesses that install systems under 100 kW. STCs are officially created once an accredited Solar Installer has commissioned the system. As a result, the cost of PV-generated electricity has fallen below the average residential electricity rate, which, depending on the state, varies between AUD 0.223 and 0.376/kWh (EUR 0.139 – 0.235/kWh).

In 2018, PV electricity systems generated about 15.4 TWh or 5.9 % of Australia's total electricity demand. The total renewable electricity share was 18.9 % and this should increase to 20 % by 2020.

2.2.2 India

For 2018, market estimates for solar PV systems vary between 10.7 and 11.2 GW, due to the fact that some statistics cite the financial year (FY) and others the calendar year. Another uncertainty is the conversion between the reported plants in AC power and the actual DC installed capacity. According to the country's Ministry of New and Renewable Energy (MNRE), at the end of July 2019, the solar power capacity of ground mounted systems was 27.9 GW_{AC} and the roof-top capacity was given with 2.1 GW_{AC} [GoI 2019], but Bridge to India reported a capacity of 34.1 GW_{AC} at the end of June 2018 [Bri 2019].

In January 2010, the Indian Jawaharlal Nehru National Solar Mission (JJNSM) was launched, in the hope that it would give impetus to the grid-connected market. The JJNSM aimed to make India a global leader in solar energy and envisages an installed solar generation capacity of 20 GW by 2022, 100 GW by 2030, and 200 GW by 2050. In 2015, the target was updated by the National Solar Mission Group of MNRE to 100 GW_{AC} by 2022 [GoI 2015].

Following the installation of just a few MW in 2010, in 2011 and 2012 installations began to pick up in 2013 and market expectations for 2019 and 2020 are in the order of 8 to 10 GW and 10 to 14 GW respectively.

The range of PPAs awarded in 2016 was between INR 4 350 and 5 010/MWh (EUR[11] 58.78 to 67.70/MWh) and dropped to INR 2 440 to 3 470/MWh (EUR 32.97 to 46.89/MWh) in the second quarter of 2017. In the meantime, the maximum allowed bids

---

[9] Average exchange rate for 2010: EUR 1 = AUD 1.40
[10] Exchange rate 09/2019: EUR 1 = AUD 1.60
[11] Exchange Rate 2016: 1 EUR = 74 IRP

have fallen to INR 2 650/MWh (EUR[12] 33.52/MWh) in 2019, but the lowest bid is still from 2017.

2.2.3 Israel

A FiT was introduced in Israel in 2008 and 4 years later the grid-connected PV market saw about 60 MW of newly connected capacity. In addition, in 2009, a renewable portfolio standard (RPS) was defined, although it took until 2011 to be completed. One of the main drivers behind the development of solar energy is energy security, and in November 2015 at COP21 in Paris, the government declared a new goal of 17 % alternative energy use by 2030 a significant increase from the then 2 %. On 3 August 2016, the Knesset passed a bill to eliminate taxes on residential solar and wind installations.

In December 2016, the Israeli Electricity Authority announced to hold four tender bidding rounds in 2017 and 2018 with 150 to 300 MW solar PV capacity each. The result of the first tender for PV projects up to 12 MW held in March 2017 was the allocation of around 235 MW of solar PV capacity.

In 2018, about 450 MW of new PV systems were connected, increasing cumulative solar PV power to 1.45 GW. Market expectations for 2019 range from 0.8 to 1.1 GW.

2.2.4 Japan

In 2018, the Japanese PV market decreased by about 12 % to 6.6 GW. Cumulative installed capacity reached 56.1 GW at the end of 2018. According to the Institute for Sustainable Energy Policies, solar photovoltaic electricity contributed 6.5% of the total electricity generation in Japan in 2018 [Ins 2019]. This was more than the share of nuclear (4.7%). The area with the highest share of PV connected to the power grid is served by Kyushu Electric Power. Here the PV share reached 11.1%, but at the same time nuclear was 25.5% in 2018. The fact that nuclear power output can hardly be adjusted, led to a number of curtailments of solar PV power from October 2018 on.

Under the FiT scheme, introduced in July 2012 and amended in the following years [METI 2013], 76.7 GW_{AC}[13] had received approval until the end of March 2019. However, only 44.6 GW_{AC} had been commissioned and were in operation. Because a significant discrepancy between actual installations and permits given emerged starting already in 2013, the Ministry of Economy, Trade and Industry (METI) started to revise the list of projects according to their actual status and revoked permits for projects that had failed to secure land and equipment by given deadlines.

Until 2010, residential rooftop PV systems represented about 95 % of the Japanese market. Since 2011, due to changes in the permit system, large ground-mounted systems as well as large commercial and industrial rooftop systems started to increase their market share and represented more than 90 % in 2016. Of the 76.7 GW_{AC} approved by the end of March 2019, only 6.4 GW_{AC} or 8.3 % comprised systems smaller than 10 kWp. However, over 95 % of these systems were actually connected to the grid. PV systems with capacities over 2 MW_{AC} represented 32 % of the approved capacity, but only 30 % of them had started operation.

On 25 May 2016, the bill for the revision of the Act on Special Measures Concerning Procurement of Electricity from RES by Electricity Utilities was enacted and put into force in April 2017. The main change besides a review of the tariffs itself is the fact that new projects with more than 2 MW capacity will have to participate in auctions. In the first auction of 2017, which had a ceiling price of JPY 21 kWh (EUR[14] 0.162/kWh), 9 projects with a capacity of 141 MW were successful. However, only 4 projects with a capacity of 41 MW actually paid the required deposit to get the approval. The second auction at the beginning of September 2018, no project was below the ceiling price of JPY 15.5/kWh (EUR 0.119/kWh), which was not disclosed to the bidder beforehand. A third auction in December 2018 resulted in 7 winning bids with a total capacity of 197 MW. The winning

---

12 Exchange Rate 2019: 1 EUR = 79 IRP

13 Please note that the METI capacity statistics is AC-based and is converted by the New Energy Development Organisation in DC-figures.

14 Exchange rate 2018: EUR 1 = JPY 130

bids ranged between JPY 14.25 and 15.45/kWh (EUR 0.110 – 0.119/kWh), below the ceiling price of JPY 15.5/kWh (EUR 0.119/kWh), which again was not disclosed to the bidder beforehand.

Starting in FY 2019, projects above 500 kW have to participate in the auction scheme. Japan's fourth solar auction, which was concluded early September 2019 ended with the allocation of 196 MW of solar capacity. However, despite 300 MW were available the auction attracted only bids of 266 MW. The successful bids ranged between JPY 10.5 and 13.99/kWh (EUR 0.086 – 0.117/kWh). The undisclosed ceiling price this time was JPY 14/kWh (EUR 0.117/kWh). It is worthwhile to note that 59 out of the 63 successful bids were for systems below 2 MW, which for the first time had to participate in an auction. A fifth auction with a volume of 416 MW is scheduled for December 2019.

New projects approved after 1 April 2017 now have three years maximum until they have to be connected. Feed in tariffs for FY 2019 were set as follows. Commercial installations (total generated power) between 10 and 500 kWp, receive a tariff of JPY 14/kWh (EUR[15] 0.117/kWh) for 20 years. For residential installations (surplus power) smaller than 10 kWp the basic FiT is JPY 26/kWh (EUR 0.217/kWh, if the system is equipped with an output control device or JPY 24/kWh (EUR 0.200/kWh) without such a device for 10 years.

In November 2009, the Japanese Government introduced the scheme to purchase surplus electricity from residential PV systems at a rate of JPY 42/kWh for 10 years. This implies that the first system will leave this scheme form November 2019 on. This means that the owners of PV systems with about 3.5 GW of capacity will see the end of their payments between November 2019 and the end of 2020. Until September 2020 companies have set up schemes to buy the surplus electricity from these owners at prices between JPY 8 and 10/kWh from November 2019 on.

As a consequence of the accident at the Fukushima Daiichi Nuclear Power Plant in March 2011 the country's energy strategy was reshaped. An official target of 28 GW_{AC} was set for PV power in 2020, which was already surpassed in FY 2015. In 2015, a new target of 64 GW of PV capacity in FY 2030 was set. The 5th Strategic Energy Plan was approved by the Japanese Cabinet on 3 July 2018 [METI 2018]. This new plan aims to increase the self-sufficiency of electricity production from 8% in 2016 to 24% in 2030 and to reduce GHG emissions by 80% until 2050.

At the current pace of PV installations in Japan, the 2030 target of 64 GW is very likely to be reached in the current FY 2019. Therefore, an initiative to increase the target to 150 GW by 2030 was started in February 2018. One year later an action plan with eight recommendations how to achieve the 2030 target was published [Ikk 2019].

2.2.5 Jordan

In 2007, when renewable energy accounted for only 1 % of the energy consumption, the Government of Jordan developed an ambitious Energy Master Plan to increase the share of renewables to 7 % in 2015 and 10 % in 2020. In April 2012, Jordan implemented the Renewable Energy and Energy Efficiency Law No 13, which established a fund to support up to 500 MW of renewable power [GoJ 2012]. According to the Middle East Solar Industry Association, Jordan had about 300 MW of net-metered systems at the end of 2018 [Mes 2019]. According to the same source, 617_{AC} MW of systems were under construction in January 2018. According to BNEF roughly 450 MW of new PV capacity was built in 2018 and market expectations for 2019 are in the range of 600 to 650 MW [Blo 2019a].

In 2015, the European Investment Bank and the French government approved loans to Jordan totalling EUR 128 million for the construction of the Green Corridor project, which aims to upgrade the electricity infrastructure to be able to accommodate the planned PV projects. The upgraded infrastructure should be operational by 2018. In April 2018, the 103_{AC} MW Quweira solar photovoltaic (PV) power plant near Aqaba was connected to the grid.

[15] Exchange rate 2019: EUR 1 = JPY 120

In October 2016, Masdar, a clean energy developer based in Abu Dhabi, UAE, signed a power purchase agreement (PPA) with Jordan's National Electric Power Company (NEPCO) for the Baynouna solar plant with 200 MW_{AC} (248_{DC} MW) capacity. The financing was arranged by IFC in January 2019 and the plant should become operational in the first quarter of 2020.

There are two module manufacturers in Jordan, Philadelphia Solar in Amman and Wiosun in Aqaba. Philadelphia Solar announced in June 2019 to increase its manufacturing capacity from 220 MW to 500 MW this year.

2.2.6 Malaysia

The Malaysia Building Integrated Photovoltaic Technology Application Project was initiated in 2000, and by the end of 2009 a cumulative capacity of about 1 MW of grid-connected PV systems had been installed.

The Malaysian Government officially launched its Green Technology Policy in July 2009 to encourage and promote the use of renewable energy for Malaysia's future sustainable development. The target was that about 1 GW must come from RES by 2015, according to the Ministry of Energy, Green Technology and Water.

In April 2011, renewable energy FiTs were passed by the Malaysian Parliament with the target of 1.25 GW being installed by 2020. The tariffs are set by the Sustainable Energy Development Authority (SEDA) for each year. For 2018 the basic tariffs for systems up to 1 MW are between MRY 0.4435 and 0.6682/kWh (EUR 0.092 to 0.181/kWh[16]), depending on the type and system size. For local manufacturing or use as building materials surcharges between MRY 0.05 and 0.1256/kWh (EUR 0.01 to 0.026/kWh) apply.

According to SEDA, PV systems with more than 380 MW_{AC} of capacity received the FiT and were operational by the end of July 2019 [Sed 2018]. Until 2020, Malaysia aims to implement 500 MW_{AC} of PV capacity under the Net Energy Metering (NEM) programme. However, the uptake of the programme is still slow.

In addition the government introduced the Large Scale Solar (LSS) Programme in 2016, which aims at a solar capacity of 1.2 GW_{AC} by 2020. In addition to the first two biding cycles with a total awarded capacity of 958 MW_{AC} throughout 58 projects, 8 projects with a capacity of 270 MW_{AC} were directly awarded until April 2018. The third bidding round was launched in February 2019 with a capacity of 500 MW_{AC}.

In 2018 around 410 MW_{AC} (490 MW_{DC}) were installed increasing the total capacity to 738 MW_{AC} (886 MW_{DC}) [Sed 2019]. The largest share with over 310 MW_{AC} came from ground-mounted utility scale projects. The annual capacity additions in this segment were larger than the total rooftop capacity of 303 MW_{AC} at the end of 2018.

Almost a dozen of companies have set up silicon solar cell or CdTe-thin film manufacturing plants in Malaysia, amounting to more than 9 GW of production capacities. In addition, there are additional smaller silicon module manufacturing companies. In total about 250 companies are involved in upstream solar PV activities such as poly silicon, wafer, cell and module production and downstream activities such as inverters and system integrators. In 2018 the number of solar jobs in the solar sector increased by over a third to more than 54 000 jobs compared to 2017 [Jas 2019].

2.2.7 Pakistan

In December 2006, the Government of Pakistan introduced the 'Policy for Development of Renewable Energy for Power Generation', which set a target of 9.7 GW of electricity generation capacity from RES by 2030 [GoP 2006]. In 2015, a FiT was introduced ranging between USD 0.142 and 0.151 per kWh depending on the size and location of the system. The Alternative Energy Development Board (AEDB) is administering the projects receiving the tariff. According to their statistics, the cumulative installed capacity within this framework was 100 MW in 2015, 400 MW in 2016, 730 MW in 2017 and 1.56 GW in

[16] Exchange rate: EUR 1.0 = MRY 4.82

2018 [Alt 2019]. According to AEDB 28 projects of 956.8 MW capacity were under development within the framework of AEDB policies and procedures in 2019.

In total it was estimated based on market data that about 3.7 GW of solar power was installed in Pakistan at the end of 2018 [Blo 2019]. Market expectations for 2019 are in the range of 1.2 to 1.3 GW.

2.2.8 People's Republic of China

According to the National Energy Administration (NEA) 44.3 GW of solar PV power was connected to the grid in 2018 increasing the total grid connected capacity to over 175 GW [NEA 2019]. About 21 GW were residential PV systems and 23.3 GW utility scale systems. Electricity production from PV systems in 2018 was 178 TWh or 2.6% of total electricity demand [Cep 2019]. Curtailment of PV generated electricity decreased from 7 TWh in 2017 to 5 TWh in 2018. Market expectations for 2019 are between 35 and 40 GW.

In the first half of 2019, 11.4 GW of new PV power capacity was connected to the grid [Nea 2019a]. On 10 July 2019, NEA announced the list of successful bidders in the first solar auction [NEA 2019b]. 366 utility scale projects with a capacity of 18.1 GW as well as 3 555 industrial and commercial projects with a capacity of 4.5 GW were successful.

The 2019 International Energy Agency (IEA) Renewable Energy Medium-Term Market Outlook expects an addition between 250 and 320 GW new PV capacity between 2019 and 2024, which would increase the total capacity between 425 and 500 GW [IEA 2019b]. However, looking at the current developments, this capacity will be reached much earlier.

In July 2017, the National Energy Administration (NEA) published the new implementation guide for the 13th Five Year Plan (2016 -2020) [NEA 2017]. In this guide, 86.5 GW of new PV capacity is foreseen, i.e. 54.5 GW ground mounted systems and 32 GW "Top Runner Programme" installations. Together with the 45 GW of PV capacity foreseen in the Poverty Alleviation Programme of the 13th Five Year Plan and the already connected capacity of over 110 GW at the end of July 2017, this could bring the total capacity to over 240 GW in 2020.

According to the 13th Five Year Plan (2016-2020) adopted on 16 March 2016, China intends to continue cut its carbon footprint and become more energy efficient. The share of non-fossil energy should increase from 12 % in 2015 to at least 15 % by 2020. Further targets are 18 % fewer carbon dioxide emissions and 15 % less energy consumption per unit of GDP in 2020 compared to 2015. Under this Plan, investment in non-fossil power should be RMB 2.3 trillion (EUR[17] 309 billion) and about RMB 2.6 trillion (EUR 349 billion) are foreseen for the upgrade of the grid infrastructure of which RMB 1.7 trillion are intended for the distribution network [Cai 2015, Wan 2016].

In 2018, 14.2% of China's energy supply came from non-fossil sources, just 0.8% short of the 2020 target. As China is ahead of its plan, the representative of the National People's Congress (NPC) Liu Hanyuan, who is also chairman of the Board of Directors of Tongwei Group, brought a number of proposals to the March 2019 sessions of the NPC calling for more ambitious targets [Cec 2019]. His proposals called for non-fossil energy targets of 20% in 2020, 30% in 2030, and over 50% in 2050.

Consolidation of the Chinese PV manufacturing industry is continuing. The ongoing price pressure for solar modules and the emergence of large 20 GW+ companies is adding to the pressure on all the solar module value chain companies. This price pressure will certainly accelerate the move of manufacturers to higher efficient products, namely changing the respective market shares of multi-and mono-silicon wafers in solar cell production. Further cost reductions come not only from higher efficiencies, but thinner wafers, made possible by the rapid uptake of diamond wafer sawing, as well. Polysilicon material consumption is expected to drop from an average of roughly 4.0 g/W at the end of 2018 to less than 3 g/W in 2023.

---

[17] Exchange rate September 2016: EUR 1.0 = CNY 7.45

2.2.9 Philippines

The Renewable Energy Law was passed in December 2008 [RoP 2008]. Under the law, the Philippines must double the energy derived from RES within 10 years. On 14 June 2011, Energy Secretary Rene Almendras unveiled the new Renewable Energy Roadmap which aims to increase the share of renewables to 50 % by 2030. This programme will endeavour to boost renewable energy capacity from the current 5.4 GW to 15.4 GW by 2030.

In early 2011, the country's Energy Regulator National Renewable Energy Board (NREB) recommended a target of 100 MW of solar installations to be implemented in the country over the next 3 years. It was suggested that a FiT of PHP 17.95/kWh (EUR[18] 0.299/kWh) was to be paid from January 2012 onwards. For 2013 and 2014, an annual digression of 6 % was foreseen. The initial period of the programme was scheduled to end on 31 December 2014.

On 27 July 2012, the Energy Regulatory Commission decided to lower the tariff in view of lower system prices to PHP 9.68/kWh (EUR[19] 0.183/kWh) and confirmed the digression rate.

The Department of Energy (DoE) reported that, by the end of 2017, more than 6.8 GW of PV projects had applied under the Renewable Energy Law and 0.91 GW, most of it commercial systems were installed [RoP 2017]. The changes from 2017 to 2018 in the national power statistics indicates that about 11 MW of new grid connected PV systems were connected [PoP 2019]. No further information about mini grids or stand-alone systems could be verified.

In 2017 two companies completed their new manufacturing sites in the Philippines. SunPower with a 400 MW solar cell and module manufacturing plant and Solar Philippines with a 600 MW module manufacturing plant.

In August 2018, the Philippine utility company Manila Electric Co. (Meralco) announced that they had received a bid of PHP 2.34 (EUR[20] 0.038) per kWh for 50 MW of solar by local PV module manufacturer and project developer, Solar Philippines.

In the first half of 2019 a 20 MW expansion of an existing 50 MW plant and a 150 MW solar farm were connected to the grid.

2.2.10 Korea

In 2018, about 2.03 GW of new PV systems were connected to the grid in South Korea, bringing the cumulative capacity to a total 7.86 GW [MOT 2019]. In the first seven months of 2019, 1.65 GW of new PV capacity was installed, more than 50% more than during the same period in 2018.

Since January 2012, has a RPS. Besides the RPS, Korea supports PV installations by the 'One Million Green Homes Programme', a building subsidy programme, a regional development subsidy programme, and the New and Renewable Energy (NRE) Mandatory Use Programme for public buildings.

The RPS mandates utilities with more than 5 000 MW generation capacity to supply 4 % of their electricity from NRE in 2016, increasing by 1 % per year to 10 % by 2022. The renewable energy mix in the Korean RPS is defined as the proportion of renewable electricity generation to the total non-renewable electricity generation. PV had its own RPS set-aside quota of for the period between 2012 and 2015.

Under the RPS, income for power generated by RES is a combination of the wholesale system's marginal electricity price plus the sale of renewable energy certificates (RECs). Depending on the type of solar installation, the RECs are then multiplied by a REC multiplier, varying between 0.7 for ground-mounted free-field systems to 1.5 for building-adapted or floating PV systems.

[18] Exchange rate for 2011: EUR 1 = PHP 60
[19] Exchange rate for 2012: EUR 1 = PHP 53
[20] Exchange rate for 2018: EUR 1 = PHP 62

Korea's has currently a target of 30.8 GW by 2030. In July 2019, MOTIE announced the plan to develop a 2.1 GW floating PV project in the Saemangeum area [MOT 2019a].

2.2.11 Singapore

In June 2012, the Energy Conservation Law was published which aims to reduce Singapore's energy intensity by 35 % from its 2005 levels by 2030 [GoS 2012]. In January 2014, the Sustainable Energy Association of Singapore (SEAS) published a White Paper sketching the pathway to installing 2 GW of PV by 2025 [Sea 2014]. According to the Energy Market Authority of Singapore, 55 MW of grid connected systems were installed in 2018, increasing the total capacity to 206 MW [EMA 2019]. In the first half of 2019 about 57 MW were already installed.

2.2.12 Taiwan

In June 2009, the Taiwan Legislative Yuan gave its final approval on the Renewable Energy Development Act to bolster the development of Taiwan's green energy industry. The goal was to increase Taiwan's renewable energy generation capacity by 6.5 GW to a total of 10 GW within 20 years. The targets for installed PV capacity were 750 MW by 2015 and 3.1 GW by 2030. The 2030 figures were gradually increased and stood at 8.7 GW at the end of 2015. Between 2009 and 2016, a total capacity of about 1 GW was connected to the grid.

In June 2016, just a month after the new president Tsai Inn-Weng took office, the Minister of Economic Affairs announced the new target of 20 GW PV power by 2025 (17 GW ground mounted and 3 GW rood-top systems). The new planning foresaw the installation of over 1.5 GW between July 2016 and July 2018. In the first half of 2018, the grid connected PV capacity increased by 470 MW to reach a cumulative capacity of 2.2 GW, some 200 MW short of the planned target. However, about 1 GW was installed in the full year 2018 increasing the total capacity to more than 2.7 GW. Market expectations for 2019 and 2020 are in the range of 1 to 1.5 GW each.

In March 2019, the Bureau of Energy under Taiwan's Ministry of Economic Affairs (MOEA) announced the FiT rates for PV electricity to be generated in 2019 [MoE 2019]. The tariffs for the second half of 2019 in the three categories are:

Type of system	Feed-in tariff [TWD (EUR[21]) per kWh]
ground-mounted	4.04 to 4.48 (0.117 – 0.130)
mounted on surface of water	4.43 to 4.87 (0.128 – 0.141)
rooftop	4.16 – 5.80 (0.121 – 0.168)

2.2.13 Thailand

Thailand enacted a 15-year Renewable Energy Development Plan in early 2009, with a target to increase the renewable energy share to 20 % of the country's final energy consumption in 2022. The original cap of 500 MW was increased to 2 GW at the beginning of 2012, as the original target had been highly oversubscribed. In addition to the Adder programme, projects were being developed with PPAs.

In July 2013, Thailand's National Energy Policy Commission (NEPC) increased the solar generation target to 3 GW and approved FiTs for rooftop (100 MW for systems smaller than 10 kW and 100 MW for systems between 10 kW and 1 MW) as well as community-

[21] Exchange rate: EUR 1 = TWD 34.5

owned ground-mounted solar plants, in addition to the Adder[22] scheme. The FiTs were set at THB 6.96/kWh (EUR[23] 0.183/kWh) for residential size systems, THB 6.55/kWh (EUR 0.172/kWh) for medium-sized building systems and industrial plants (< 250 kW) and 6.16 THB/kWh (0.1627 EUR/kWh) for large building and industrial plants.

The 2015-2036 Alternative Energy Development Plan (AEDP 2015) was approved by the NEPC on 17 September 2015 [MoE 2015]. The plan aims to increase the use of solar energy with installation capacity of 6 GW by 2036.

In 2018 about 160 MW of new solar capacity was connected to the grid and increased the cumulative capacity to over 3.3 GW [Blo 2019a].

At the beginning of 2019 new national Power Development Plan (PDP) was agreed by the Thai Government. This new plan includes the increase of non-hydro renewable power from 20 to 30% by 2037. It also increases the target of solar power capacity able to sell to the state grid to 12.7 GW. In addition off-grid independent power supply (IPS) can develop solar installations without selling to the grid.

The Electricity Generating Authority of Thailand (EGAT) has plans to build 16 floating solar plants on its nine hydro-dam reservoirs with a combined capacity of 2.7 GW_{AC} between 2020 and 2037. The first biding round for a floating solar power plant on the Sirindhorn Dam with a capacity of 45 MW_{AC} (58_{DC} MW) closed on 20 August 2019 [Ega 2019].

2.2.14 United Arab Emirates (UAE)

At the moment the UAE has no federal energy policy, because the constitution gives autonomy in management and regulation of energy and resources to the individual emirates. Nevertheless, there is growing recognition of the need for coordination, consistency, and co-investment among emirates and the Ministry of Energy is now leading the country's first effort to develop a national strategy. IRENA has developed a Renewable Energy Roadmap for 2030, which calls for 21 GW of solar PV power to be installed by 2030 [Ire 2015]. According to a press report by 'The National', the UAE is aims to generate 25 % of its electricity with clean energy (nuclear and solar) by 2030 [Nat 2016]. At the end of 2018 about 220 MW of PV power was operational.

In January 2015, a consortium led by ACWA Power (Saudi Arabia), won the bid of the 260 MW Phase II (200 MW_{AC}) of the Mohammed bin Rashid Al Maktoum Solar Park (Dubai) with a bid of USD 5.84/kWh for a 25-year PPA starting in 2017 [Acw 2015]. The third phase of 800 MW_{AC} was won by a consortium led by Masdar with a bid of USD 29.9 per MWh [Mub 2016]. The project will be commissioned in three steps:

- 200 MW_{AC} – operational since May 2018,
- 300 MW_{AC} – operational since June 2019 and
- 300 MW_{AC} by April 2020.

In September 2016, a consortium led by JinkoSolar (China) and Marubeni (Japan) entered a bid of USD 24.2 per MWh for the Abu Dhabi Electricity and Water Authority's (ADWEA) Sweihan solar power tender [Nat 2016a]. This power plant with a capacity of 1.2 GW was connected to the grid in the first half of 2019. In July 2019, the Emirates Water and Electricity Company (EWEC) launched a 2 GW tender. The deadline for bids is the fourth quarter of 2019 and commercial operation should commence in the first quarter of 2022.

2.2.15 Vietnam

In December 2007, Vietnam's National Energy Development Strategy was approved. It prioritises the development of renewable energy and includes the following targets: to increase the share of renewable energies from negligible to about 3 % (58.6 GJ) of total commercial primary energy in 2010, to 5 % in 2020, 8 % (376.8 GJ) in 2025, and 11 % (1.5 TJ) in 2050. The updated Power Development Plan 2011-2020, which was approved

22 The "Adder" scheme was the Thai version of additional premium to the wholesale electricity price.
23 Exchange rate: EUR 1 = THB 38

by the Prime Minister in March 2016 set new targets for PV power: 850 MW by 2020 and 12 GW by 2030 [PMV 2016].

In April 2017, the Prime Minister of Vietnam issued Decision 11/2017/QD-TTg, which came into effect on 1 June 2017 and expired on 30 June 2019. This decision introduced a feed-in tariff for grid connected systems and set minimum efficiency requirements (15% module efficiency). By the end of June 2019 the country had 4.46 GW_{AC} of grid connected PV capacity equal to 8.3% of Vietnam's electricity capacity. In the second half of 2019 over 600 MW_{AC} of additional PV capacity is scheduled to be finalised.

In April 2019 the Ministry of Industry and Trade of Vietnam (MOIT) published the final draft to extended the duration of the second FIT from 1 July 2019 to 31 December 2021. New proposed tariffs will vary from USD 0.067/kWh to USD 0.109/kWh.

After three projects in solar-cell manufacturing stalled in Vietnam, the first solar cell and module manufacturing plant operated by Boviet Solar Technology Co. Ltd. and located in Bắc Giang, started production in June 2014. In the meantime another five companies have started solar cell manufacturing in the country.

2.2.16 Emerging markets

Bangladesh: In 1997, the Government of Bangladesh established the Infrastructure Development Company Limited (IDCOL) to promote economic development in Bangladesh. In 2003, IDCOL started its Solar Energy Programme to promote the dissemination of solar home systems (SHS) in the remote rural areas of Bangladesh, with financial support from the World Bank, the Global Environment Facility, the German KfW, the German Technical Cooperation, the Asian Development Bank (ADB) and the Islamic Development Bank. At the end of 2018, more than 6.8 million SHSs (50-60 W) had been installed in Bangladesh. According to the International Renewable Energy Agency (IRENA), over 133 000 people work in the PV sector in Bangladesh.

The Renewable Energy Development Targets call for an additional 3 100 MW of renewable energy capacity to be installed by 2021. Most of the new capacity will be provided by solar (1 676 MW, 54 %) and wind (1 370 MW, 44 %). There are also targets for waste-to-energy (40 MW), biomass (7 MW), biogas (7 MW) and hydro (4 MW).

In February 2017 the cabinet committee on public purchase approved the proposals for four solar power plants with a total capacity of 258 MW in different places across the country [Dha 2017]. The guaranteed offtake prices vary between BDT 10.2 and 11.04/kWh (EUR[24] 0.104 and 0.113/kWh). At the end of the first quarter 2019 about 325 MW of solar PV capacity was operational. This includes four larger grid connected solar power plants with a combined capacity of 30_{AC} MW (42_{DC} MW.

Indonesia: In February 2014, the Indonesian Parliament adopted a revised National Energy Plan (NEP14), which replaces the 2006 National Energy Plan and it went into force as Government Regulation No 79/2014 on 17 October 2014 [RoI 2014]. The plan aims 23 % share of NRE of the primary energy supply in 2025. Solar photovoltaic energy should contribute with a capacity of 6.4 GW. In June 2016, Indonesia's Ministry of Energy and Mineral Resources (ESDM) issued Decree ESDM 19/2016, which aims for 5 GW of new solar power to be installed within the next 2 to 3 years [MEM 2016]. The regulation sets quotas for the different parts of the country as well as FiTs, which range between USD 0.145 and 0.25 per kWh. The first nationwide total quota was 250 MW, with the largest share of 150 MW for Java, and the smallest quota for Papua and West Papua with 2.5 MW each. However, there was very little development.

In January 2017, the Ministry of Energy and Mineral Resources issued two new regulations on the Principles of Power Purchase Agreements (MD 10/2017) and on the Utilisation of Renewable Resources for Electricity (MD 12/2017) [MEM 2017]. Before the issuing of MD 12/2017, the feed in tariffs were set by the government. Now the tariffs are the result of negotiation between the state-owned power utility Perusahaan Listrik Negara (PLN) and independent power producers. The regulation includes the capping of the tariff, if the regional supply costs are above the national average. On the other side, if the

[24] Exchange rate: EUR 1 = BDT 98

regional supply costs are below the national average, the maximum tariff for renewable energy plants is equal to the regional average. This mechanism applies to all renewable energy plants except geothermal and waste-to-energy plants.

Since the issuing of the new regulations, a number of PPAs with over 250 MW capacity have been signed between PLN and various developers. These plants should have become operational in 2018, but so far limited progress has been made. Total installed PV power in Indonesia was estimated at around 130 MW, with more than 80% off grid, at the end of 2018.

Indonesia's local content requirements demand 60% by 2019 for solar PV modules after an amendments of the regulations in 2017. However, Indonesia's PV module manufacturing capacity is in the order of 90 MW, which is inadequate for the annual capacity addition required to achieve the 6.4 GW solar PV target by 2025.

Kazakhstan: The development of renewable energy was one of the priorities of the State Programme of Accelerated Industrial and Innovative Development for 2010-2014. The main goal is to develop a new and viable economy sector for growth, innovation and job creation. In addition, it drives the development of RES for the electricity sector in Kazakhstan and is regulated by the Law on Supporting the Use of Renewable Energy Sources, adopted in 2009 [RoK 2009]. In February 2013, the Kazakh Government decided to install at least 77 MW of PV by 2020 [GoK 2013]. In September 2014, during a conference organised by Astana Solar, plans were discussed to build 28 PV plants with over 700 MW capacity up until 2020 [Kaz 2014].

In 2011, JSC NAC Kazatomprom and a French consortium headed by Commissariat à l'énergie atomique et aux énergies alternatives (CEA) jointly began the Kaz PV project which aims to produce PV modules based on Kazakhstan silicon [Kaz 2011]. The first stage of the project was concluded in January 2013, when a new 60 W PV module production plant was opened in Kazakhstan's capital city Astana.

In January 2014, a 2 MW ground-mounted solar power plant was completed in the city of Kapchagay in the Almaty Province [Bis 2014]. At the end of 2017, the total PV capacity was estimated at about 70 MW, and should increase to 1 GW in 2020. In 2018 about 150 MW were installed and another 100 to 150 MW should be installed in 2019.

In November 2017 the Green Climate Fund (GCF) – European Bank for Reconstruction and Development (EBRD) Kazakhstan Renewables Framework was approved. About EUR 560 million are foreseen for the construction of 8 to 11 renewable energy projects in Kazakhstan, with a total capacity of 330 MW.

Iran: Despite the excellent solar resources solar photovoltaic power only increased from 53 MW in 2005 to 67 MW in 2011. Then in 2010, the Iranian government announced plans to build 2 GW of renewable energy capacity between then and 2015**.** Despite this announcement the uptake of renewable energy was slow. In 2016, a decree of the Minister for Energy [MoE 2016], approved by the Cabinet, provided the legal basis for a feed in tariff and PPAs with renewable power producers. In August 2019, the installed solar photovoltaic capacity was 342 MW out of which 28 MW are residential installations.

Myanmar: In 2015/16, the country has a rural electrification rate of about 34 %, with vast regions beyond the reach of the main grid. In February 2014, the government published its Draft Electricity Law which includes the possibility of setting up small power producers in Myanmar. The World Bank commissioned a study — 'Myanmar National Electrification Program (NEP) Roadmap and Investment Prospectus' — which should develop a plan to realise 100 % rural electrification by 2030.

The Asia Development Bank published a report in March 2014 which revealed that about 11 % of the population in the Mandalay Region was already using PV SHS with 80 to 200 W [ADB 2014]. About 4.5 % of all villages were electrifies with solar systems at the end of 2015. In the first phase (2016-2021) of the national energy plan 2016-2021, it is foreseen that 461 000 households in Sagaing, Ayeyarwady and Thanintharyi regions as well as Kayin, Chin, Rakhine and Shan states will be electrified by solar systems.

The total installed PV capacity was estimated with 25 MW at the end of 2017. In November 2018, phase one (40 MW_{AC}) of a 170 MWAC solar plant in Minbu Township, in upper

Myanmar's Magwe Region was completed. After intensive testing it was officially connected to the national grid in June 2019. The plant should reach its full capacity in 2021.

Qatar: In 2008 the country launched the Vision 2030, which set a national target of 2% renewable energy by 2030 and a 10 GW target for solar energy. Recently, the county set a target of generating 20% of its electricity using solar energy by 2020. This would require about 1.8 GW of capacity, however, the mix between PV and solar thermal electricity generation (STEG)25 is not clear yet. It is worthwhile to note, that Qatar depends by 87% on desalination for its freshwater supply and consumes about 30% of the counties energy demand.

The installed PV capacity has increased from 3.2 MW in 2014 to about 5 MW in 2018. In 2019 Qatar General Electricity and Water Corporation (Kahramaa) has received five bids from international developers to develop a solar farm with up to 800 MW_{AC} in two stages until 2022.

In March 2017, Qatar Solar Technologies (QSTec), which already operates a 300 MW module factory in the Doha industrial zone that it had successfully produced its first polysilicon at its plant in Ras Laffan Industrial City [Qst 2017]. The factory reported a manufacturing capacity of 8 000 MT of polysilicon and should be expanded to 50 000MT in the future.

Yemen: In 2002, the Renewable Energy Department under the Ministry of Electricity and Energy (MEE) with the goal to promote and support renewable energy projects in the country was established. In 2009, the department was extended and reorganized into two departments for Solar Energy and Wind Energy. In the same year, the government set a target for grid connected renewable electricity at 15% for 2025.

For COP21 Yemen pledged as its Intended Nationally Determined Contribution (INDC) under the UNFCCC measures for the off-grid electrification of individual households and rural electrification measures based on renewable energy (photovoltaic systems, solar home systems (SHS), wind energy where feasible and biomass, both in stand-alone and hybrid schemes).

The target for solar home systems is to install 110 000 systems with a capacity of 5.5 MW by 2025.

According to media reports, Sanaa received around 18 hours of power daily before the outbreak of the civil war in September 2014. In early July 2016, several neighbourhoods in the capital received around four hours of power every five days. This situation in the countryside is even worse and let to a trend to install more and more small PV systems to provide the basic needs of electricity.

Between 2012 and 2018 the cumulative installed PV capacity has increased from 1.5 MW to an estimated over 400 MW.

25 Also used term: concentrated solar power (CSP)

2.3 Americas

2.3.1 Argentina

In 2006, Argentina passed its Electric Energy Law which established that 8 % of electricity demand should be generated by renewable sources by 2016 [GoA 2006]. The law also introduced FiTs for wind, biomass, small-scale hydro, tidal, geothermal and solar for a period of 15 years. In July 2010, amongst other RES, the government awarded PPAs to six solar PV projects totalling 20 MW, however only 7 MW were actually realised. By the end of 2017, about 25 MW (15 MW off-grid) of PV systems were operational.

In late 2015 the National Government passed the Renewable Energy Act 27191, which laid the foundation for a new promotional legal framework to promote the uptake of renewable energy [GoA 2015]. The Act was then regulated by the Presidential Decrees 531/16 and 882/16 [GoA 2016, a], which set a target of 20% of the final electricity demand by 2025.

To achieve the 2025 targets the RenovAr auction programme was launched in May 2016 and in three bidding rounds 147 projects with a combined capacity of 4.47 GW (1.73 GW_{AC} of PV projects) were successful. The median bids of the PV projects declined from USD 59.75/MWh in the first round to USD 42.84/MWh in the addition of the third round – called RenovAr 2. Despite the fact that the first projects from round 1 should become operational in 2018, most of these projects are delayed. The first RenovAr projects with a capacity of 167 MW_{AC} (202 MW_{DC}) became operational in 2018. According to the Argentinan Foinace Ministry 18 solar photovoltaic RenovAr projects were operational the beginning of September 2019. The installed capacity of these plants was about 420 MW_{AC} (510 MW_{DC}). Installation of PV modules at that the largest solar farm in Argentina the 300 MW_{AC} (370 MW_{DC}) in Cauchari, Jujuy, was finished in September 2019. It is expected that commercial operation can start before the end of the year after the Altiplano Transformer Station is ready.

In June 2019 a small PV tender allocated 97.75 MW_{AC} to 13 PV projects.

2.3.2 Brazil

At the end of 2018, the Brasilein Ministry of Mines and Energy reported a cumulative installed PV capacity of 2.3 GW_{AC} [MME 2018]. This shows that 1.2 GW_{AC} of new capacity was installed in 2018. In the first eight months of 2019 about 1.17 GW_{AC} were added [MME2019]. The distribution was about 2.25 GW_{AC} of utility scale PV installations and 1.11 GW_{AC} of distributed PV systems.

In July 2017, Brazil has released its long-awaited 10-Year Energy Expansion Plan proposition, PDE 2026, projecting the country to reach more than 13 GW of solar PV deployment by 2026. Brazil's energy agency EPE expects non-hydro renewables to reach up to 48% of the energy mix by 2026. Under the reference scenario large scale PV plants should contribute 9.7 GW and distributed PV systems should add another 3.5 GW.

Solar technology was eligible to participate in one of the two December 2017 auctions and projects with 574 MW_{AC} power were successful. For the Auction in April 2018, Brazil's energy regulator (ANEEL) had set a ceiling price of BRL 312/MWh (EUR[26] 63.67/MWh). The lion's share of the 1 GW auctioned capacity was won by solar projects with a combined capacity of 807 MW_{AC} at an average price of BRL 118/MWh (EUR 24.08/MWh).

In June 2019, an A-4 auction resulted in average solar prices of BRL 67.48/MWh (EUR[27] 14.7/MWh), where six solar PV projects won 211 MW_{AC} out of 402 MW_{AC} available. The lowest bid came from a 30 MW_{AC} project with BRL 64.99/MWh (EUR 14.1/MWh).

2.3.3 Canada

In 2018, about 160 MW of new PV power were connected to the grid and increased the total cumulative installed PV capacity to 3.05 GW. Most of the systems are installed in

26 Exchange rate 2018: EUR 1: BRL 4.9
27 Exchange rate 2019: EUR 1: BRL 4.6

Ontario, which has a feed-in programme since 2009. However, new installations were only eligible for the programme until December 2016. Electricity consumers in Ontario who produce some of their own power from a renewable resource (systems up to 500 kW) can participate in the 'net-metering' initiative. Ontario's Long-term Energy Plan sets a target of 10.7 GW of non-hydro RES by 2021.

Solar auctions were first introduced in 2015 but little press was made until 2018. The first projects should start commercial operation in 2019.

2.3.4 Chile

On 30 December 2015, the President of Chile Michelle Bachelet, signed the Supreme Decree approving Chile's new long-term energy strategy 'Energy 2050' [GoC 2015]. The new policy sets a goal of generating 70 % of national electricity generation from renewable sources by 2050.

In the first quarter of 2012, the first MW-size PV system was installed in the northern Atacama Desert. More than 660 MW of PV power was connected to the grid in 2017, increasing the total PV capacity to about 1.8 GW_{AC} at the end of 2017. According to the Comisión National de Energía the connected solar capacity increased to 2.64 GW_{AC} until July 2019 [CNE 2019].

On 17 August 2016, Comisión National de Energía announced the results of electricity auction '2015/01'. The lowest bid for a PPA, fixed in USD for 20 years, came from a solar project to deliver 255 GWh/year at USD 29.1 per MWh. The average price of all winners for 12.4 TWh/year was USD 47.6/MWh.

In 2017, 2 200 TWh of electricity were auctioned and the results announced in November 2017. The auction was divided in three time blocks, where the electricity has to be delivered.

- Block 1A: 11pm – 8am
- Block 1B: 8am – 6pm
- Block 1C: 6pm – 11pm.

The lowest bid in the 2017 power auction was $21.48/MWh, with an average price of $32.5 MWh. Enel and GPG Solar Chile submitted the lowest bids with $21.48 MWh and $24.80/MWh respectively.

Market expectations for 2019 are around 500 MW for new solar PV capacity.

2.3.5 Dominican Republic

As early as 2007, the law promoting the use of renewable energy, which set a target of 25 % renewable energy share by 2025 was passed [GoD 2007]. At that time, about 1 to 2 MW of solar PV systems were installed in rural areas, which increased to over 5 MW in 2011. Despite the fact that Corporación Dominicana de Empresas Eléctricas Estatales signed various PPAs totalling 170 MW in 2011 and 2012, no information about the operation of significant capacities could be found. It was estimated that by mid-2014 about 10 MW of PV installations were in operation, including a 500 kW system at the Union Médica hospital in Santiago. In March 2016, Phase I (34 MW_{AC}) of a 67 MW_{AC} solar plant was inaugurated in the Monte Plata province. At the end of 2017 it was estimated that about 110 MW were insytalled. In July the so far largest solar photovoltaic power plant with 58 MW_{AC} (73 MW_{DC}) in Guayubín, Montecristi was connected to the grid [Fss 2018]. However two additional project in Mata de Palma, San Antonio de Guerra (50 MW_{AC}) and the Canoa Solar project with 25 MW_{AC}, in Barahona, were moved to 2019. In June 2019 two additional PV power projects with 100 MW_{A}C and 200 MW_{AC} were announced.

2.3.6 Honduras

In 2007, Honduras enacted a law to promote renewable energy generation, with 20-year income tax breaks and a waiving of import tariffs on renewables components. In 2013, the government introduced a premium tariff for the first 300 MW to be installed until

30 June 2015. The General Electricity Industry Act, which adds a USD 0.03 premium for solar projects not eligible for the premium tariff was enacted in May 2014 [GoH 2014]. So far the Congress has approved 620 MW of solar PV power to be installed.

In November 2015, the National Electric Energy Company reported that 389 MW of solar PV power was connected to the grid in 2015 increasing the total capacity to 485 MW. In 2017 approximately 20 MW were installed to increase the total capacity to 560 MW (450 MW_{AC}). In 2018 around 60 MW_{AC} of new PV power was added and increase the total capacity to 511 MWAC (636 MW_{DC}).

Electricity generation from PV plants in 2017 was 993 GWh equal to 10% of total generation or 16% of final electricity consumption.

2.3.7 Mexico

In 2008, Mexico enacted the Law for Renewable Energy Use and Financing Energy Transition to promote the use of renewable energy [GoM 2008]. In 2012, the country passed its Climate Change Law, which anticipates a reduction in greenhouse gas emissions of 30 % below the business-as-usual case by 2020 and 50 % by 2050 [GoM 2012]. It further stipulates a share of renewable electricity of 35 % by 2024. A new National Energy Strategy 2012-2026 was approved in 2013, which moved the 35 % renewable electricity goal to 2026.

According to the Mexican Solar Energy Association (Asolmex) the installed solar PV power capacity has increased from 3.07 GW_{AC} at the end of 2018 to 4.06 GW_{AC} in June 2019. This consists of 693 MWAC decentralised and 3.36 GW centralised PV power installations. The IEA Medium-Term Renewable Energy Market Report 2016 forecasted a cumulative PV capacity of over 7 GW by 2020 [IEA 2016].

The results of the country's first power auction were published on 30 March 2016. Solar power with almost 1.6 GW and 4 TWh won contracts for PPAs between MXN 614.14/MWh (EUR[28] 29.24/MWh) and MXN 1 169.78/MWh (EUR 55.70/MWh) [CNC 2016]. The second auction in September 2016 resulted in contracts for 184 MW of additional solar PV power, but in addition more than 4.9 million CECs were given to solar PV projects for a total energy production of 4.84 TWh [CNC 2016a]. All systems have to be operational on 1 January 2019. A third auction was held in November 2017. 3.45 million CECs and 1.3 GW_{AC} was awarded to solar photovoltaic projects. The prices per MWh varied between MXN 242.10 and 298.14 (EUR[29] 10.86 – 13.27/MWh) whereas the CEC prices varied between MXN 95.82 and 149.07 (EUR 4.30 – 6.69) [Ern 2017]. The winning projects must start to deliver electricity on 1 January 2020.

On 27 September 2018, Enel Green Power México announced that it has connected its 828 MW Villanueva solar photovoltaic plant in Viesca, Coahuila and its 260 MW Don José solar park in San Luis de la Paz, Guanajuato [Ene 2018d].

2.3.8 Panama

In March 2016, the Government approved the National Energy Plan (NEP), 2015-2050 [GoP 2016a]. The plan includes a roadmap to use at least 70 % of RES in the energy mix by 2050. In April 2016, the National Authority of Public Services (ASEP) announced, that they will remove the cap of 500 kW for self-consumption, if the customer does not inject more than 25 % of his own consumption into the grid [Ase 2016]. In January 2015, Panama's Electricity Transmission Company (La Empresa de Transmisión Eléctrica S.A. (ETESA)) awarded in the first solar energy auction five PPAs to solar projects providing 660.2 GWh/year for prices between USD 80.2/MWh and 104.8/MWh starting from 1 January 2017 [Ete2015].

According to the Autoridad Nacional de los Servicios Públicos (ASEP) 58 MW of solar capacity was added increasing the cumulative solar capacity to 185 MW at the end of 2018 [Ase 2018]. In 2018 solar photovoltaic power generated 230 GWh of electricity or 2.7% of total production.

---

[28] Exchange rate 2016: 1 EUR = 21 MXN

[29] Exchange rate 2018: 1 EUR = 22.3 MXN

2.3.9 Peru

In 2008, Peru passed the Legislative Decree 1002 which made the development of renewable energy resources a national priority. The decree states that by 2013 at least 5 % of electricity should be supplied from renewable sources, such as wind, solar, biomass and hydro. In February 2010, the energy regulatory commission Osinergmin (Organismo Supervisor de la Inversión en Energía y Minería) held the first round of bidding and awarded four solar projects with a total capacity of 80 MW. A second round was held in 2011, with a quota of 24 MW for PV. About 85 MW of PV systems had been installed by the end of 2012. The National Photovoltaic Household Electrification Program, launched in 2013, aimed to supply PV electricity to 500 000 households by means of 12 500 solar systems by 2016.

On 16 February 2016, Osinergmin announced that they had awarded two PV projects with a total capacity of 184.5 MW to deliver 523.4 GWh of electricity/year at prices of USD 47.98/MWh (144.5 MW_{AC} with 415 GWh) and USD 48.50/MWh (40 MW_{AC} with 108.4 GWh) [Osi 2016]. Since then there was no further auction for solar power.

In March 2018, Enel Green Power Peru reported the inauguration of their 180 MW (144.5 MW_{AC}) plant in Rubí, province Moquegua [Ene 2018e]. The second project awarded in the 2016 auction to Engie with 40 MW_{AC} (44.2 MW_{DC}) was connected in May 2018 and increased the operational solar power capacity to about 320 MW.

2.3.10 United States of America

With over 10.6 GW of newly connected PV power, the United States had reached a cumulative PV capacity of almost 62.7 GW by the end of 2018 [Woo 2019]. In terms of nominal capacity, solar accounted for 29 % of new power capacity in 2018, second only to natural gas. With over 6.1 GW utility PV installations accounted for 58% of the new installed solar photovoltaic power capacity. The top ten States — California, Texas, North Carolina, Florida, Nevada, New York, New Jersey, Minnesota, Arizona and Massachusetts still accounted 75 % of the US PV market, and California alone had a market share of 31.8 %.

Following the Section 201 trade case, tariffs on modules were announced in January 2018. For 2018 the tariff was 30% and declines by 5 percentage points annually to 15% in 2021. This move resulted in a slowdown of the market in the first half of the year but almost recovered in the second half. Market expectations for 2019 vary between 10 and 13 GW, whereas the expectations for 2020 are in the range of 13 to 17 GW.

PV utility projects based on PPAs, with a total capacity of 37.9 GW, were under contract, but not yet operating in Q3 2019 [Woo 2019a]. In Q3, 8.7 GW of these projects were under construction. In the first half about 2.6 GW of utility scale projects were installed and it is estimated that the about 8 to 8.5 GW of utility projects will be connected to the grid before the end of 2019. In addition more utility scale projects with more than 56 GW have been announced, but not yet signed a PPA.

Many state and federal policies and programmes have been adopted to encourage the development of markets for PV and other renewable technologies. These comprise direct legislative mandates (such as renewable content requirements) and financial incentives (such as tax credits). One of the most comprehensive databases on the different support schemes in the USA is maintained by the North Carolina State University Solar Centre. The Database of State Incentives for Renewables and Efficiency (DSIRE) is a comprehensive source of information on state, local, utility and selected federal incentives that promote renewable energy. It also includes descriptions of all the different support schemes. The DSIRE website http://www.dsireusa.org/ and the corresponding interactive tables and maps (giving details) are highly recommended.

2.3.11 Emerging markets

In 2014 the government of **Cuba** announced that 24% of the country's generated electricity should come from renewable energy sources by 2030. To reach this goal the government plans to install 700 MW_{AC} of solar PV capacity. According to Cubasolar, the gov-

ernment signed Law No 345, "On the Development of Renewable Sources and the Efficient Use of Energy," on 23 March 2018. So far it has not yet been published in the official Gazette.
In February 2015, the Cuban newspaper reported the opening of the first Cuban solar module factory with 15 MW capacity by the electronics manufacturer Empresa de Componentes Electrónicos Ernesto Che Guevara [Gra 2015].
It is estimated that about 32 MW_{AC} of PV systems were installed in Cuba in 2017. The total capacity at the end of the year was about 65 MW_{AC} (90 MW_{DC}).
In 2018, about 30 MW of additional PV capacity was installed. In the first half of 2019, four solar farms, financed by the Abu Dhabi Fund for Development and IRENA, with a combined capacity of 10 MW were connected to the grid. In the Mariel Special Development Zone a 50 MW_{AC} project, the first 100% foreign-owned and operated renewable-energy plant, is under construction and should become operational at the end of 2019. The project is owned by Hive, a UK based company, which formed a joint venture with SE Energy Investment Co., a British subsidiary of China's Shanghai Electric Group Ltd. It is estimated that a total capacity of about 100 MW could be installed in 2019.

The **Guatemala** National Energy Policy 2013-2027 came into force in February 2013 [GoG 2013]. The National Energy Plan defines the promotion of renewable energy resources as one of its guiding principles and sets a target of 80% of electricity generation from renewable energy resources. In January 2015 a 58 MW (50 MW_{AC}) utility plant was connected to the grid in Chiquimulilla, Santa Rosa. The second 35 MW (30 MW_{AC}) stage of the plant became operational in the second half of 2015. It is estimated that about 130 MW of PV capacity was installed in Guatemala at the end of 2018. Electricity genreated from solar photovoltaic systems was 208 GWh or 1.7% of the total generation in 2018 [MEM 2019].

In 2012 the government of **El Salvador** enacted the Master Plan for Renewable Energy Development (2012 – 2026), which at that had a target of 90 MW_{AC} of PV capacity by 2026. In 2014 El Salvador's power distributor Delsur conducted an auction where 4 solar projects were awarded a combined capacity of 94 MW. A second auction for 100 MW PV capacity was held in 2016. The latest auction was in 2018 with a solar PV capacity of 28 MW.
In April 2017, 101 MW of solar capacity were connected to the Salvadorian grid by Neoen [Neo 2017]. The company was awarded 76 MW in the 2014 tender and negotiated an additional 25 MW with electricity distributor Del Sur. In November the same company announced the financial close for its Capella Solar project, a solar farm with 140 MW with a 3 MW/1.8 MWh storage [Neo 2018]. This project should become operational in 2020. Another three 10 MW projects were connected by AES El Salvador until September 2018.

In 2009 **Jamaica** published its National Energy Strategy 2009 – 2030, which aims to provide 20% of the energy needs by renewable energy sources in 2030 [MEM 2009]. The first large solar plant at Content Village, Clarendon, with 20 MW_{AC} (28 MW_{DC}) became operational in August 2016 [Wrb 2016]. A second utility scale PV plant at Paradise Park, Westmoreland, with a capacity of 37 MW_{AC} (51 MW_{DC}) started commercial production in June 2019.

The parliament of **Nicaragua** passed the Renewable energy promotion law, which declares that renewable energy based power generation is of national interest in 2005 and prolonged the incentives for electricity from renewable energy sources in 2017 [RoN 2005]. In December 2017, the Ministry of Energy and Mines published the new regulation for self-consumption and net metering in the official gazette [MEM 2017a]. The new regulations allow the owners of solar photovoltaic electricity systems with a capacity of up to 5 MW to sell their surplus of electricity, which is not self-consumed to Nicaraguan distribution companies. However, little progress has been reported. The installed PV capacity was estimated at around 22 MW at the end of 2018.

2.4 Africa

Despite Africa's vast solar resources and the fact that in large areas the same PV panel can produce, on average twice as much electricity in Africa as in Central Europe, there has been only limited use of solar PV electricity generation up to now. According to the latest update of the JRC resource study in Africa[30], solar PV electricity is the most competitive technology for almost 40 % of the total population in Africa. Until the end of the last decade, the main application of PV systems in Africa was in small solar home system (SHS) and the market statistics for these are extremely imprecise or even non-existent. However, since 2012, major policy changes have occurred and a large number of utility-scale PV projects are now in the planning stage. In 2015, IRENA published 'Africa 2030: A Roadmap for a Renewable Energy Future'. The roadmap identified modern renewable technology options across the sectors and across countries, which could collectively supply 22 % of Africa's total final energy consumption (TFEC) by 2030. This is more than a fourfold increase compared to the 5 % share in 2013. According to the roadmap, PV solar power should contribute 70 TWh or 4 % of TFEC produced by 31 GW of PV systems in 2030.

Overall, the (documented) capacity of installed PV systems rose to more than 5 GW by the end of 2018, an increase by two orders of magnitude compared to 2007. Current African PV targets for 2020 are in excess of 10 GW, but it will be difficult to reach this target in time.

2.4.1 Algeria

In 2011, Algeria's Ministry of Energy and Mines published its Renewable Energy and Energy Efficiency Programme which aims to increase the share of renewable energy used for electricity generation to 40 % of domestic demand by 2030. The plan anticipates 800 MW of installations until 2020 and a total of 1.8 GW by 2030. In February 2014, the ministry introduced two FiT regimes, one for systems between 1 and 5 MW and one for systems larger than 5 MW. It was estimated that about 5 MW of small decentralised systems and a few larger systems in the multi-kW range were installed at the end of 2013.

According to the Renewable Energy Development Centre (CDER), the National Renewable Energy programme for Algeria (2015- 2030) now has a target of 22 GW of renewable power with a share of 13.5 GW of PV power by 2030.

Aures Solaire a 51/49 joint venture between Algerian firm Condor Electronics and Vincent Industrie (France) opened a 30 MW solar module factory located in the industrial zone of Ain Yagout in April 2017. Condor Electronics already owns and operates a 75 MW module plant at the same industrial zone since 2013.

In January 2017 the government adopted a decree to launch a 4 GW solar PV tender and in March 2017, the regulatory framework for the implementation was published in the Official Journal [Jou 2017]. The solar plants should be built in the High Plains of northern and southern Algeria. The first tender with a capacity of 150 MW closed in June 2019. However, the Algerian Electricity and Gas Regulation Commission (CREG) received only eight offers with a combined capacity of 90 MW.

In 2015 and 2016, PV systems with about 350 MW were newly installed, but in 2017 and 2018 only very few new systems were connected to the grid. It is estimated that the total PV capacity –on- and off-grid was just about 420 MW at the end of 2018.

2.4.2 Burkina Faso

A National Policy for Sustainable Economic and Social Development went into force in August 2016 [MEF 2016]. A key element is the access of the population to electricity, extremely important in a country were only 3% of the rural population have access to electricity. A tender with a total capacity of 67.5 MW was launched, but none of the projects is operational yet.

[30] RE2nAF tool for off-grid options for rural Africa Web site: http://re.jrc.ec.europa.eu/re2naf.htm

The Zagtouli PV plant was already initiated in 2013 and received financing from the EIB. The 33 MW grid connected PV plant was finally commissioned in late November 2017. In January 2018, Burkina Faso's Ministry of Energy revealed a plan to install eight additional solar parks with a combined capacity of 100 MW in the country. This plan was amended with an increased target of 155 MW in November 2018.

In December 2017, Wärtsilä started operation of a 15 MW (12 MW_{AC}) solar power plant for Essakane Solar SAS [Wär 2017]. The PV plant is next to a 55 MW heavy fuel oil plant and both installations provide off-grid power to the Iamgold Eassakane SA. No significant new PV power capacity was added in 2018.

In January 2019, a tender for a 10 MW and a 20 MW solar PV plant was published. The plants should receive PPAs, partly financed by a grant of the World Bank for the financing of the Power Sector Support Project (PASEL).

During the G5 Sahel summit in Ouagadougou on 16 September 2019, the heads of state gave strong support to Desert to Power, an initiative launched by the Africa Development Bank (AfDB) in 2018. The initiative aims to develop 10 GW of solar power for the 250 million people across the Sahel.

2.4.3 Cape Verde

Cape Verde's Renewable Energy Plan (2010-2020) aims to increase the use of renewable energy to 50 % by 2020 through the use of PPAs. Law No 1/2011 establishes the regulations for independent energy production. In particular, it lays down the framework conditions for the set-up of independent power producers using renewable energy (15-year PPAs), and for self-production at user level. It creates a micro-generation regime, regulates rural electrification projects, and states the tax exemption on all imported renewable energy equipment.

The 2018 – 2040 Master Plan for the Electricity Sector was published in 2018, [GoC 2018]. This plan presents a strategy to supply 54% of electricity by renewable energy sources in 2030. 150 MW of new solar photovoltaic power, more than 60 MW of wind and 630 MW of storage capacity are foreseen.

By the end of 2012, two centralised grid-connected PV plants with 7.5 MW had been installed. In addition, there are a number of smaller off-grid and grid-connected systems. At the end of 2015, about 10 MW of PV power was operational [Ire 2016]. A 2 MW solar/wind hybrid project to provide electricity and fresh water on the Island of Brava had been approved by the IRENA/ADFD Project Facility [Ire 2016]. At the end of 2017 about 14 MW of PV capacity was operational. The energy and water service provider Águas de Ponta Preta on the island of Sal commissioned a new 1.4 MW plant in December 2018.

2.4.4 Egypt

In September 2014, the Ministry of Electricity and Energy and the Regulatory Agency launched a FiT support system for solar PV and wind projects with capacity less than 50 MW. The target of the programme is to install 300 MW from small PV installations below 500 kW, and 2 GW PV plants between 500 kW up to 50 MW. The tariffs at that time varied between EGP 84.8 to 102.5/kWh (EUR[31]0.085 to 0.103/kWh) depending on the size of systems.

The first two rounds of the FiT programme were heavily oversubscribed and around 2 GW of PV capacity was allocated. The majority of these projects, which received a 25-year FiT contract are located in the 2 GW_{AC} Benban solar complex, near Aswan in upper Egypt. The project consists of 41 individual plants with 31 identical 50 MWAC (64 MWDC) and 10 projects with different sizes due to the shape of the area [Nre 2016]. A significant number of projects only reached financial close in the second half of 2017 after the International Finance Corporation (IFC), the European Bank for Reconstruction & Development (EBRD) and the African Development Bank (AFDB) approved loans of almost USD 1.2 billion for 27 different projects. In December 2017, the Egyptian Electricity Transmis-

31 Exchange rate: 1 EUR = 9.95 EGP

sion Company (EETC) issued a request for prequalification (RfP) for 600 MW_{AC} of solar PV capacity to be developed West of the Nile.

The first solar plant at the Benban solar complex, Infinity with 64 MW (50 MW_{AC}) became operational at the end of 2017. An estimated 800 MW_{AC} (1 GW_{DC}) were installed in 2018. According to the Daily News Egypt 27 plants with a combined capacity of 1.2 GW_{AC} (1.5 GW_{DC}) were connected to the grid in July 2019 [Dai 2019]. In addition, Scatec announced in August 2019 the grid connection of two additional plants with a capacity of 100 MW_{AC} (130 MW_{DC}).

2.4.5 Ethiopia

In February 2013, a 20 MW module manufacturing plant was opened in Addis Ababa, **Ethiopia**. The factory is a joint project between SKY Energy International and Ethiopia's Metals and Engineering Corporation (METEC). According to press reports, the factory was upgraded to 100 MW manufacturing capacity in 2015 [Eth 2015]. Press reports confirmed the Ethiopian Electric Power Corporation (EEP) approved three solar plants with a capacity of 300 MW in the eastern region of the country [Ven 2013]. In August 2016, EEP announced to tender the three projects, which will be located in Metahara, Umera and Mekelle [Ena 2016].

In 2016, EEP signed an agreement with IFC to advise on the development of up to 500 MW of solar power under the Scaling Solar initiative. The pre-qualification bid for two 125 MW_{AC} PV plants as part of the World bank's Scaling Solar programme in November 2017 resulted in the announcement of a dozen qualified bidders in March 2018.

In October 2017, it was announced that a consortium with Enel and the Ethiopian infrastructure company Orchid Business Group, had been selected as the developers of the 100 MW_{AC} Metahara project [Ene 2017].

In April 2019, Ethiopia initiated its Scaling Solar Round 2 tender by issuing a Request for Pre-Qualification (RFQ) for up to 500 MW_{AC}, which was later increased to 750 MW_{AC}.

It is estimated that a solar PV capacity of about 15 MW was operational at the end of 2018.

2.4.6 Ghana

In 2011, the Parliament of Ghana passed the Renewable Energy Bill which aims to increase the proportion of renewable energy, particularly solar, wind, mini-hydro and waste-to-energy in the national energy supply mix and to contribute to mitigating climate change [RoG 2011]. The bill sets a goal of renewable energy constituting 10 % of national energy generation by 2020. At the end of 2012, there were a few thousand SHS and a few off-grid systems providing an estimated 5 MW installed in the country. In 2012, a number of companies announced the signature of PPAs in Ghana. However, none of these projects have been realized so far. In May 2013, the Volta River Authority (VRA) inaugurated its first solar power plant at Navrongo, with a capacity of 2.5 MW. In April 2016, Beijing Xiaocheng Company (BXC) connected the first 20 MW of their 40 MW PV solar power plant at Onyandze to the grid [Ecr 2016]. In September 2018 IPP, Meinergy Ghana Ltd started the commercial operation of its 20 MW solar plant in Gomoa, Onyaadze [Faa 2018].

In April 2016, Accra-based developer Strategic Power Solutions (SPS) opened a 30 MW solar module plant in Tema, outside of Accra.

A number of large scale solar power plants with a combined capacity of close to 300 MW have been announced over the last years, but none of the projects has reached the financial closure yet.

In March 2017, the government announced to restart the Rooftop Solar Programme and the Energy Commission aims to realise 200 MW of rooftop PV capacity in the medium term. However, no tangible progress can be reported so far.

2.4.7 Mauritania

In 2011, the country set up a Master Plan for the Production and Transport of Electricity until 2030 and adopted its third Poverty Reduction Strategy Paper (PRSP) action plan (2011 – 2015) [IMF 2013]. The number of households with access to electricity rose from 30% in 2008 to 38.8% in 2014 [ONS 2014].

The PRSP has set a target of raising the share of renewable energy in the national energy mix to 15% by 2015 and 20% in 2020. As part of the actions taken, the Sheikh Zayed 15 MW solar photovoltaic plant in Nouakchott was connected to the grid in 2013. The tender for a second PV plant in Nouakchott with 30 MW closed February 2016. The plant size was increased later to 50 MW and was connected to the grid by the end of 2017.

In 2016, 8 smaller projects with 16.6 MW were installed increasing the total capacity to approximately 35 MW. Total PV power capacity reached 86 MW at the end of 2018.

2.4.8 Morocco

The Kingdom of Morocco's solar plan was introduced in November 2009, with the aim of establishing 2 000 MW of solar power by 2020. To implement this plan, the Moroccan Agency for Solar Energy (MASEN) was founded in 2010. Solar electricity technologies, solar thermal electricity generation[32] and PV will all compete openly. Earlier in 2007, the National Office of Electricity (ONEE) had already announced a smaller programme for grid-connected distributed solar PV electricity, with a target of 150 MW of solar PV power. Various rural electrification programmes using PV systems have been running for a long time. At the end of 2012, Morocco had installed about 20 MW of PV systems, mainly under the framework of the Global Rural Electrification Program, and about 1 to 2 MW of grid-connected systems.

In February 2015, ONEE announced their plan to tender various PV power projects of 20 to 30 MW each with a total capacity of 400 MW [One 2015]. The first plants should have been operational at the end of 2017. In April 2015, the World Bank announced its decision to support the first phase of 75 MW. The pre-qualification process for PV Noor I, three plants with a combined capacity of approximately 170 MW solar power was launched by MASEN in summer 2015. 20 consortia were pre-qualified by MASEN in December 2015 to submit bids for the three plants Noor Ouarzazate, Noor Laayoune and Boujdour Noor. According to press reports, three consortia from Saudi Arabia won the bids with prices in the range of USD 60/MWh. It was confirmed that Noor Laayoune (85 MW) and Boujdour Noor (20 MW) started commercial production in 2018.

Two companies in Casablanca are producing PV modules — Droben Energy, a subsidiary of the Spanish Droben company, with 5 MW, and Cleantech with 15 MW capacity. In May 2016, Jet Contractors, a Moroccan construction company, announced a Joint Venture with Haereon Solar (PRC) and Société d'Investissements Energétiques (SIE) to build a 160 MW solar cell and module manufacturing plant in Morocco [Jet 2016]. The company already operates a 30 MW cell and module plant, which as phase I of the project will be converted to manufacture cells and modules according to Haeron's quality standards.

Morocco's Office National de l'Electricité et de l'Eau Potable (ONEE), provides solar power to more than 19,000 homes in more than 1,000 rural villages at the end of 2017.

It is estimated that about 140 MW of PV system capacity was installed at the end of 2018.

2.4.9 Senegal

In 2008 the Ministry for Renewable Energy (MER) was created and the National Agency for Renewable Energies (ANER) was established in 2013. The country enacted a renewable energy law in 2010 [Jou 2011], which calls for the diversification of the counties energy supply and a promotion of the use of renewable energy sources.

In 2016 the first competitive tender solar PV projects were launched through the framework of the World Bank's 'Scaling Solar' initiative, which should enable 200 MW of PV

[32] Also used term: concentrated solar power (CSP)

power in Senegal. This has auctioned 100MW of solar capacity and the pre-qualification round closed in October 2016 [Com 2016].

The first utility scale projects with 20 MW solar PV at BokholIt and 22 MW in Malicounda started operation in October and November 2016. In 2017, this was followed by two 30 MW plants in Santhiou Mékhé near Méouane and in Ten Merina, near Dakar. For 2018, a capacity addition of about 40 MW was estimated.

In April 2018, the results of a 60 MW_{AC} the 2017 Scaling Solar initiative in Senegal tender were announced. The solar plant located in Kahone will have a tariff of EUR 0.0380/kW and the plant in Touba will have a tariff of EUR 0.0398/kWh [SSS 2018]. The International Finance Corporation (IFC), announced in July 2019 to have finalised the financing for the first two Scaling Solar projects in Senegal.

2.4.10 South Africa

South Africa has a rapidly increasing electricity demand and vast solar resources. In 2008, the country enacted its National Energy Act, which calls for a diversification of energy sources, including renewables, as well as fuel switching to improve energy efficiency [GoS 2008].

In 2011, the Renewable Energy Independent Power Producer Procurement Programme (IPP) was set up with rolling bidding rounds. Four rounds have already taken place: in 2011 (630 MW), 2012 (420 MW), 2013 (450 MW) and 2014 (415 MW). The overall target is 3.725 GW and that for solar PV is 1.45 GW. Between the first round (closing date: 4 November 2011) and the fourth round (closing date: 18 August 2014) the average bid price fell from ZAR 2.65/kWh (EUR[33] 0.265/kWh) to ZAR 0.62/kWh (EUR[34] 0.044/kWh). The long awaited fifth round with a renewable capacity of 1.8 GW was finally announced in June 2018 and should be conducted in November 2018.

Developers who had won allocations in the fourth bidding round of REIPP had to wait until April 2018 when the PPAs were finally signed.

As a result of the long delay to sign the PPAs of the fourth round, about 250 MW, less than half of the 2016 PV capacity, was connected in 2017. It is estimated that about 200 MW of new PV capacity was added in 2018.

Due to the country’s local content rules, more and more manufacturers along the solar value chain are setting up plants in South Africa. A non-exhaustive list of industry activities can be found in the 2017 report [Jäg 2017].

2.4.11 Zambia

On 21 June 2017, Zambia officially launched its 7th National Development Plan (SNDP) (2017-2021) [GoZ 2017]. In 2016, 97% of the electricity capacity was hydro, but it is envisaged that with increasing electricity demand (+150 to 200 MW capacity per annum will be needed) the non-hydro share will increase to 15% by 2030.

In July 2015, Zambia’s Industrial Development Corporation (IDC) signed an agreement with IFC to explore development of two large-scale solar projects through Scaling Solar. The results of the first auction were announced in December 2017 [IFC 2017]. Two projects, one with 54 MW for USD 0.0602/kWh and a 34 MW (USD 0.078/kWh) project were selected.

Construction at the 54 MW solar plant in Bangweulu started in December 2017 and started commercial operation in 1Q 2019.

The Ngonye solar PV plant ,Lusaka South Multi-Facility Economic Zone, with a capacity of 34 MW (28 MW_{AC}) received financing from the EIB, announced in the framework of IFC's Scaling Solar programme [EIB 2018]. Construction started in August 2018 and the plant was connected to the grid in April 2019 [Ene 2019a].

33 Exchange rate 2012: EUR 1 = ZAR 10
34 Exchange rate 2015: EUR 1 = ZAR 14

With support from the German Cooperation (GET) provided through KfW, the government of Zambia has tendered a capacity of 100 MW_{AC} for solar projects with an individual installed capacity of up to 20 MW_{AC} in April 2019. In the end six solar PV projects with a combined capacity of 120 MW_{AC} from three different power producers were successful. The lowest bid was USD 39.99/MWh for two 20 MW_{AC} projects, whereas the highest successful bid was USD 48.00 again for two 20 MW_{AC} projects.

2.4.12 Emerging markets

In 2008, **Kenya** introduced FiTs for electricity from RES, but solar power was only included in 2010, when the tariffs were revised [GoK 2010]. However, only a little over 560 kW of PV capacity was connected to the grid in 2011; the majority of the 14 MW of PV systems were off-grid installations. In 2011, Ubbink East Africa Ltd., a subsidiary of Ubbink B.V. (Doesburg, the Netherlands) opened a solar PV manufacturing facility in Naivasha with an annual output of 30 000 modules. The plant produces modules for smaller PV systems, such as SHS. Current estimates for Kenya's PV market put average annual sales of home systems at 20 000 to 30 000 and solar lanterns at 80 000. It is estimated that the total capacity of SHS, telecommunication applications, diesel-PV hybrids and the few grid-connected systems will be about 25 to 30 MW at the end of 2016. In March 2016, the Rural Electrification Authority (REA) board approved the construction of a 75 MW (55 MW_{AC}) solar power plant in Garissa [Rea 2016]. It is interesting to note that the solar plant was financed through concessional funding from the Government of China. After a number of delays, construction started in the second half of 2017 and was finished in September 2018.

Two solar plants with a capacity of 40 MW_{AC} each, in Eldoret - Uasin Gishu county, signed funding agreements with the EIB in September 2018 [EIB 2018a]. The two plants are currently under construction and should be connected to the grid in 2020.

The power sector of **Mozambique** is dominated by hydro-electric power generation. A large proportion of the electricity generated in Mozanbique is exported to South Africa and Zimbabwe via the Southern African Power Pool (SAPP). On the other hand, the electrification rate of Mozambique is 28%, below the average of the Southern African Development Community (SADC) countries.
Between 2011 and 2013, the Government of Mozambique and Fundo de Energia (FUNAE) conducted a study on renewable energy resources in the country. While they identified a solar potential of 23 TW, only 0.6 GW of solar priority projects were listed.
Between 2011 and 2018 the installed capacity has increased from 1 MW to 17 MW, mostly off-grid and mini-grid applications. The first large scale plant was opened by Scatec in June 2019, the 40 MW Mocuba Solar PV plant. The project is funded through the project "Climate Investment Fund (ICF)" and Emerging Africa Infrastructure Fund (EAI). A second plant with 30 MW is developed by the NEOEN energy group.

In 2005, **Nigeria** passed the Power Reforms Act as well as the National Renewable Energy Master Plan for Nigeria which set targets for solar to contribute 5.0 MW, 75 MW, and 500 MW in 2010, 2015 and 2025, respectively. In November 2015, the government of Nigeria approved the FiT regulation, which went into force in February 2016. The tariffs apply to PV systems between 1 and 5 MW and caped at a capacity of 380 MW by 2018.

In February 2014, it was reported that Nigeria's first module manufacturing plant had been completed and is now operational with a nameplate capacity of 10 MW [Pvt 2014]. The plant was built in Sokoto by German firm JVG Thoma.

According to various press reports, the government-owned energy purchasing company Nigerian Bulk Electricity Trading (NBET) has already signed solar PPAs with 14 developers. The MWh price of these PPAs was set at USD 115 and could add about 1.4 GW but so far only two projects could sign a PPA [Ene 2019b].

It is estimated that less than 30 MW of solar PV power were operational at the end of 2018.

At the end of 2012, **Tanzania's** Ministry of Energy and Minerals (MEM) published its Strategic Plan 2011/12-2015/16, in which the strategic objective to enhance the sustainable development and management of energy resources for national development was formulated [MEM 2012]. As a follow-up, the Scaling-up Renewable Energy Program (SREP) was published in April 2013 [MEM 2013]. Despite that the SREP calls for a cumulative installed PV capacity of 60 MW by 2017 and 120 MW by 2020 not much has been realised yet. Cumulative PV capacity is estimated below 10 MW at the end of 2018.

In 2018, Tanzania's state-owned power utility the Tanzania Electric Supply Company Ltd (Tanesco) published a tender for the construction of several large-scale PV projects with a combined capacity of 150 MW [Tes 2018].

In 2009, **Tunisia** launched its Solar Plan. It is a Public-Private Partnership spanning 2010 to 2016. The plan aims to increase the share of RES in the total Tunisian energy mix from 0.8 % to 4.3 % by 2014. The PROSOL ELEC programme to promote the installation of grid-connected systems was set up to handle investment subsidies and guaranteed loans as well as power purchase for 1 to 2 kWp solar PV systems [Ste 2013]. PV capacity was estimated below 50 MW at the end of 2018.

Since 2017, Tunesia has launched three tenders for projects up to 1 MW and for systems not larger than 10 MW. In round one and two 12 plants with a capacity of 10 MW and 14 plants with a capacity of 1 MW were awarded [RoT 2018, 19,a,b].

In May 2018, the Ministry of Energy and Mines published a call for private projects to build 1,000 MW of renewable energy power plants, 500 MW wind and 500 MW solar. In July 2019 five bids, all below USD 30/MWh, were received.

A 30 MW module factory run by Green Panel Technology Jurawatt Tunisie came into operation in 2014 [Jvg 2014]. The company is a joint venture between Tunisia Green Panel Tech and JVG Thoma, Germany.

In July 2013, the Cabinet of **Uganda** approved the new Rural Electrification Strategy and Plan 2013 – 2022 [GoU 2013]. The overall objective of this plan is to increase the rural electrification rate from 7% to 26% within the given period. In 2014, the Electricity Regulatory Authority (ERA) announced that with effect from 1st January 2015, the procurement of new capacity from solar technology will be subject to a competitive tendering process initiated by the ERA in accordance with the Electricity Act, 1999 Chapter 145, Laws of Uganda [Era 2014].

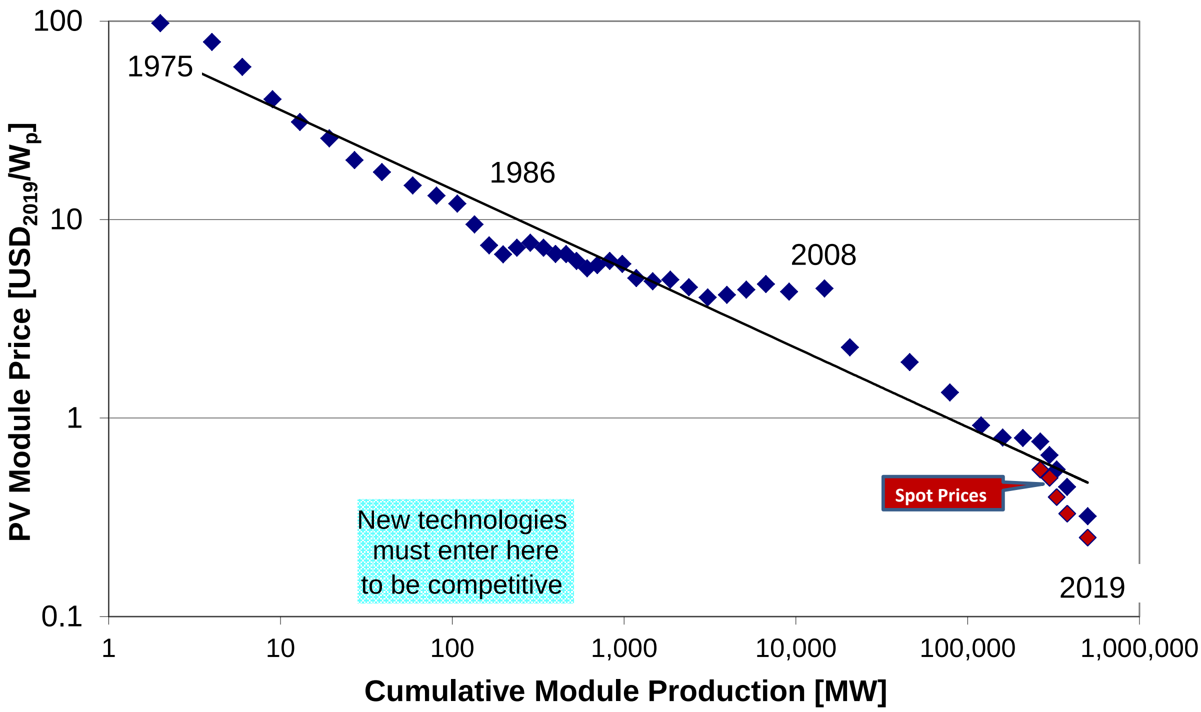
Under the Global Energy Transfer for Feed–in–Tariffs (GET-FiT) Programme, launched in 2013, 2 solar PV plants with 10 MW each were built. Funding for the programme comes from the European Union, Germany, Norway and the United Kingdom. The 10 MW Soroti PV plant started operation in November 2016, followed by the Tororo plant in September 2017 [Get 2017] and by the Kabulasoke solar power plant (24 MW) in January 2019. The total installed capacity is estimated at 70 MW at the end of 2018.

3 Electricity costs and the economics of PV systems

Over the last four decades, solar module prices have fallen following a price-experience or 'learning' curve with an average learning rate of about 80 %, i.e. the average selling price (ASP) of solar modules fell by 20 % for each doubling of production volume (Fig. 8). This development was driven not only by technological developments but also by market conditions. It is interesting to note that between 2004 and the second half of 2008 the price of PV modules remained fairly constant at roughly USD_{2016} 4 to 4.5/Wp. This occurred despite the fact that manufacturing technology continued to improve and companies significantly scaled up their production. The reason for this was the expanding markets in Germany and Spain, where the only slowly changing FiTs enabled project developers to be profitable at that price. This was coupled with shortage of polysilicon between 2004 and 2009, which limited silicon solar cell production and prevented effective pricing competition, thus providing an opening for thin-film technologies to enter the market. The temporary silicon feedstock shortage and the market entry of companies offering turnkey production lines for thin-film solar cells led to a massive expansion of investments in thin-film capacities between 2005 and 2009. The market share for thin-film modules increased until 2009, when it reached almost 20 %, although it has declined steadily since then to about 4% in 2018.

The market entrance of potential new technologies has to happen at prices comparable to current market prices but at production volumes a few magnitudes lower than silicon.

Figure 9: Price-experience curve for solar modules (ASP)



Source: Bloomberg New Energy Finance (BNEF) and PV News

Between 2008 and the end of 2012, there was a massive 80 % drop in the price of modules, with 20 % in 2012 alone, creating serious financing problems for all companies and leading to the closure of a significant number of them [Blo 2013]. This drastic price drop was a consequence of the huge overcapacities as a result of the very ambitious investments spending between 2005 and 2011. Between 2013 and 2015, the price decline was relative moderate before it accelerated again at the end of 2015. At the same time the volatility of the module spot prices has increased significantly.

PV system prices have followed the lowering of module prices but at a slower pace. The share of the non-technical costs has steadily increased over the years, despite an overall cost reduction. For the technical components of a PV system there is a global market, e.g. modules, inverters, cables, etc., and these prices are very similar worldwide, if we do not consider taxes and duties. However, prices for installed PV systems still vary significantly depending on the size, type of installation and country where it is installed [Blo 2019b]. The reasons for these differences are manifold, ranging from the different legal requirements for permits, licensing and connection to the grid to the different maturity of local PV markets, with impacts on competition between system developers and installers. PV system prices are changing rapidly, not only in Europe, which opens up new opportunities for PV in a rapid growing number of countries to become one of the major electricity providers in the near future.

3.1 LCOE

A common measure for cost comparison of power-generation technologies is the concept of the LCOE[35]. LCOE is the price at which electricity must be generated from a specific source to break even over the project's lifetime. It is an economic assessment of the cost of the energy-generating system, including all the costs over its lifetime: initial investment, operations and maintenance including land rent if applicable, end-of-life management, cost of fuel, and cost of capital. It can be calculated using a single formula, such as:

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

where:

LCOE	= average lifetime levelised electricity generation cost
I_t	= investment expenditures in the year t
M_t	= operational and maintenance expenditures in the year t
F_t	= fuel expenditures in the year t, which is zero for PV electricity
E_t	= electricity generation in the year t
r	= discount rate
n	= financial lifetime of the calculation

This calculation delivers the LCOE of the generator, but falls short of describing the full LCOE for the total system, which covers profile cost (including flexibility and utilisation effects), balancing costs and grid costs. These cost categories have to be added to all electricity-generating technologies LCOEs, whether they are conventional or RES (Fig. 10). There are a number of reasons why the LCOEs of different power-generation technologies differ in different regions and at different times, and this has an influence on the merit-order effect. For example: (1) Full-load hours: different power-generation technologies have different full-load hours depending on the type of resource, such as hydro, solar, wind, etc., or the type of power plant, for instance base-load, medium- or peak-load plants; (2) All combustion technologies incur fuel costs, which have different degrees of volatility and associated risk, and depend on the type of delivery contract and/or geographic region; (3) Demand variations; (4) Central or decentralised power generation; (5) Weather forecasting accuracy for wind and solar; and (6) Market regulations and trading opportunities, etc.

35 LCOE formula used by the National Renewable Energy Laboratory (NREL): http://www.nrel.gov/analysis/tech_lcoe_documentation.html

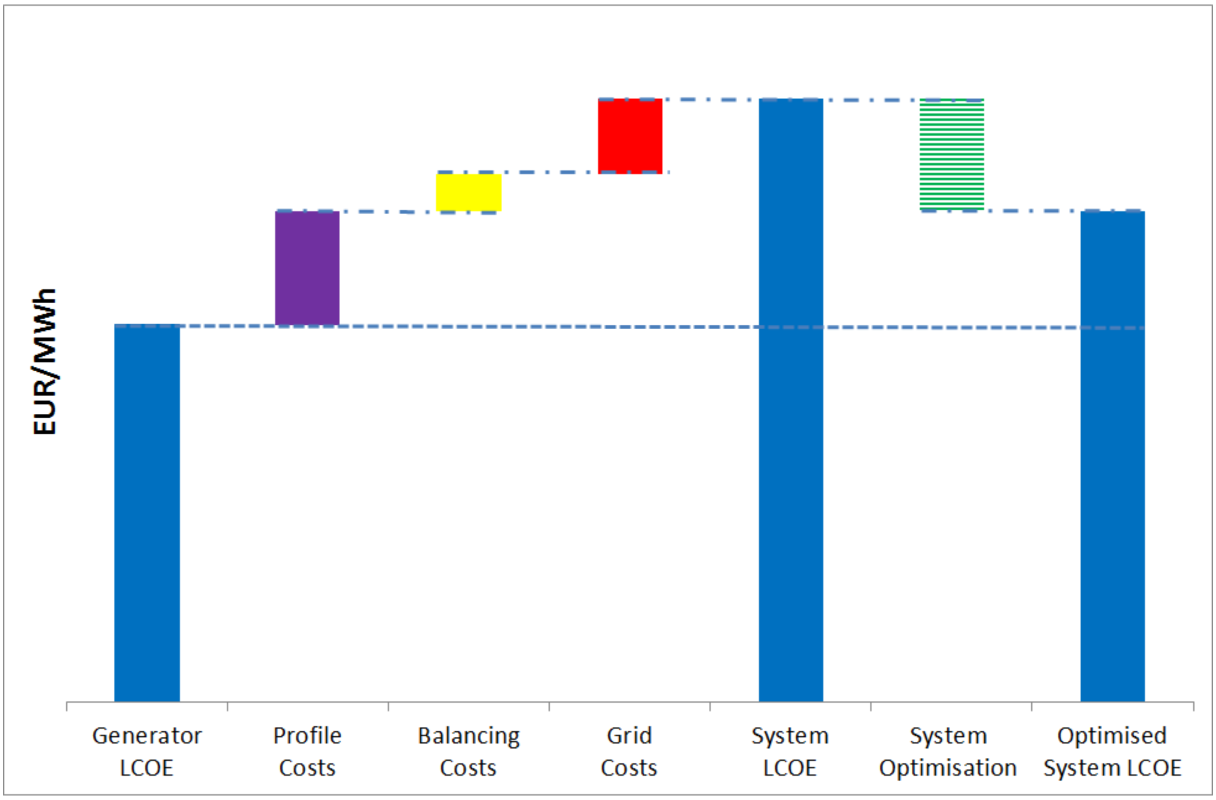
The benchmark against which the different generator and system LCOEs must be compared are the market prices in the respective segments of a given market.

Although a considerable number of studies have calculated, estimated or modelled the value of renewable electricity from variable resources, most of them have investigated the market penetration of a single renewable energy source, like wind or solar, rather than a portfolio of different RES and optimised integration technology options [Hir 2013 and references, Uec 2013]. It should also be noted, that the current market designs still do not price-in the environmental and health costs of the different power generation technologies [Wan 2015].

For solar PV electricity, the market value depends on the kind of application. In the case of residential or commercial systems, the benchmarks are the residential or commercial electricity retail rates. For large utility-scale solar farms, the market value is more difficult to determine and PPAs are a good indicator of how utility companies evaluate them.

The following sections show the LCOE of different PV systems and the economic and technical possibilities for PV to contribute to profile, balancing and grid costs.

Figure 10 : Schematic of the components in a PV System LCOE



3.2 Influence of financing costs on LCOE

Over the last 40 years, hardware costs of PV systems have decreased drastically due to a combination of research activities and market development. Technical installation costs have decreased as well, driven by best practices and increasing competition levels in the installers market. Given the fact that the largest share of investments into a solar PV electricity generation system has to be done at the beginning of the project and no fuel costs are inexistent, the weighted cost of capital (WACC), often also referred as the discount rate, has a critical impact on LCOE.

The WACC can be calculated as follows:

$$WACC = \frac{E}{V} * Re + \frac{D}{V} * Rd\ (1 - Tc)$$

Where:

Re	= cost of equity
Rd	= cost of debt
E	= market value of the firm's equity
D	= market value of the firm's debt
V	= E + D
E/V	= percentage of financing that is equity
D/V	= percentage of financing that is debt
Tc	= corporate tax rate

As shown above, not only the equity to debt ratio but the corporate tax rate has a significant influence on the WACC. Cost of debt is very much dependent on the economic situation in a given country and the financial stability of the company looking for debt. Therefore, WACC for a given project can vary not only where it is realised, but also by whom the project is realised. The range of costs for debt in the first half of 2019 for a number of key markets is reported between 140 bps and 1 100 bps, whereas return of equity expectations were between 4% and 13% [Blo 2019b].

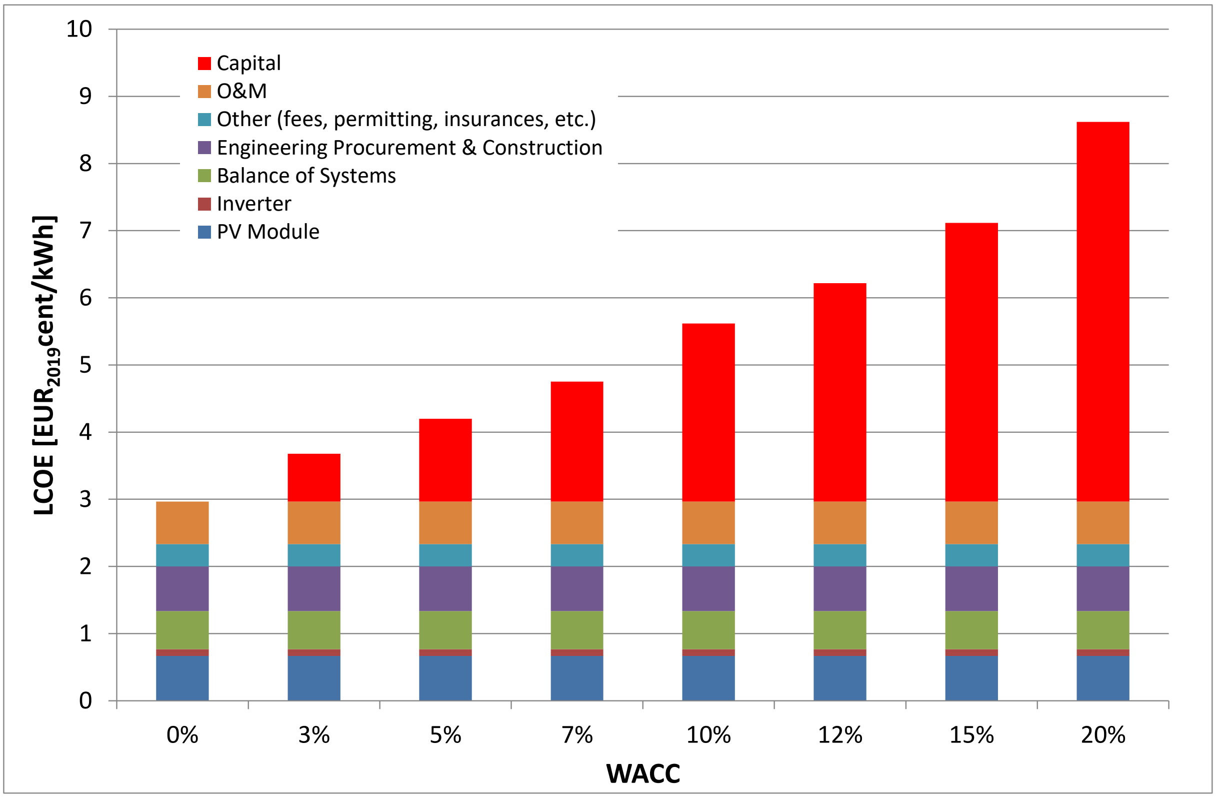
In this context, it is noteworthy to mention that the low bids and PPAs in the United Arab Emirates, Chile, Portugal as well as in Africa have only been possible by a combination of excellent solar resource, high debt shares and low debt costs. In the case of Africa, the low costs of debt were possible through an exchange rate guarantee by the World Bank, lowering the investors risk as the offtake price is guaranteed in USD [WBG 2017].

To show the impact of financing on the LCOE, the following benchmark assumptions for a non-tracking large scale system to be operational in 2020 were taken:

CAPEX EUR_{2019} 700 per kWp, operational expenditure (OPEX) EUR 9.5 per kW/year, 1 500 kWh/kW per year, financial lifetime of 20 years. Local taxes and administration costs were not considered.

As can be seen in Figure 11, with a WACC of 7 %, the financing costs exceed the hardware and technical installation costs, and at a WACC of 12 %, the financing costs are more than 50 % of the total LCOE. It becomes obvious that PV electricity generation costs are more and more depending on a low financial risk environment with low financing costs than on high solar irradiation. It also highlights that the government risk mitigating policies can be more efficient to support PV development than introducing financial support when none of the energy forms are subsidised, or supported in the same way.

Figure 11: Influence of WACC on LCOE

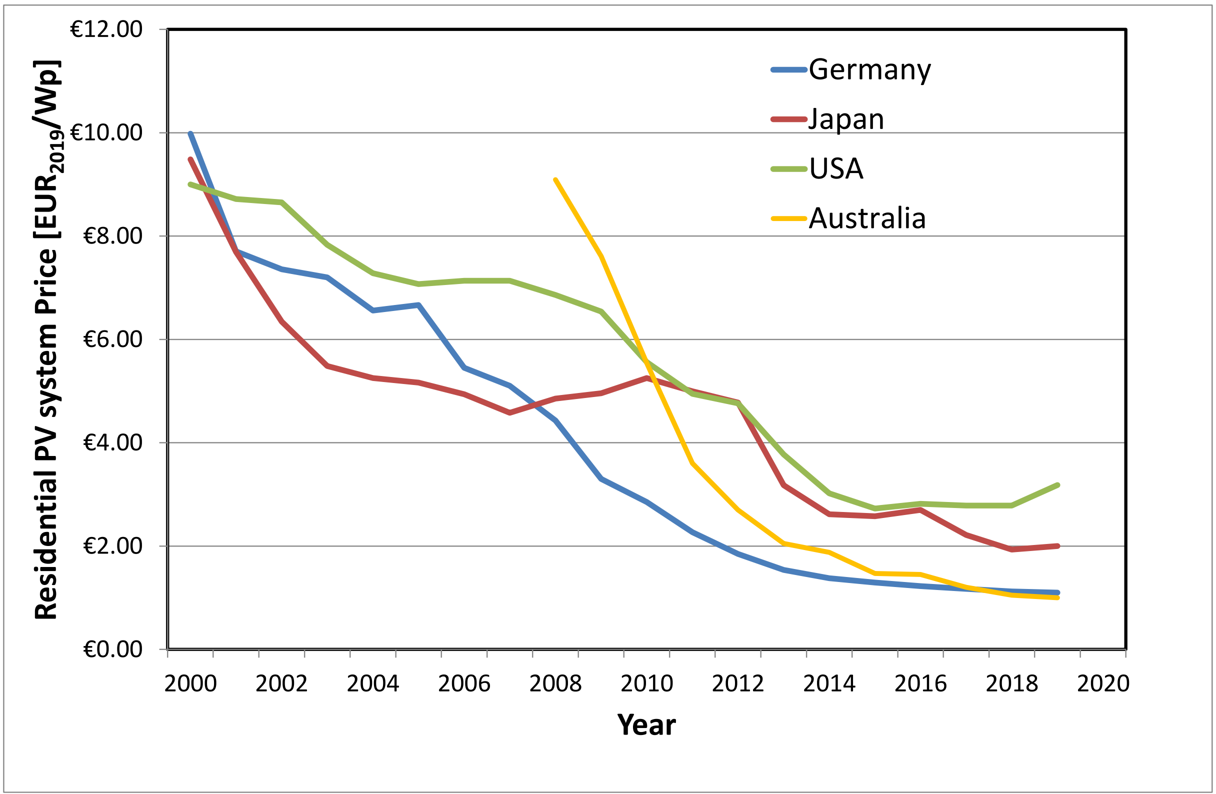


3.3 LCOE of residential grid-connected PV systems

Over the last decade, prices for residential grid-connected PV systems have decreased significantly, as shown in Figure 12. The increase in PV system prices in Japan, between 2007 and 2010 as well as the increase in the USA from 2014 to 2016 are due to changes in exchange rates; in the local currency the prices fell.

Please note that customers in the USA still receive a 30% federal tax credit (until 2021), which in parts is responsible for the overall higher prices. The price increase in 2018 and 19 is attributed to higher module prices due to the import tariffs as well as a high demand.

Figure 12: Residential PV system price development over the last two decades

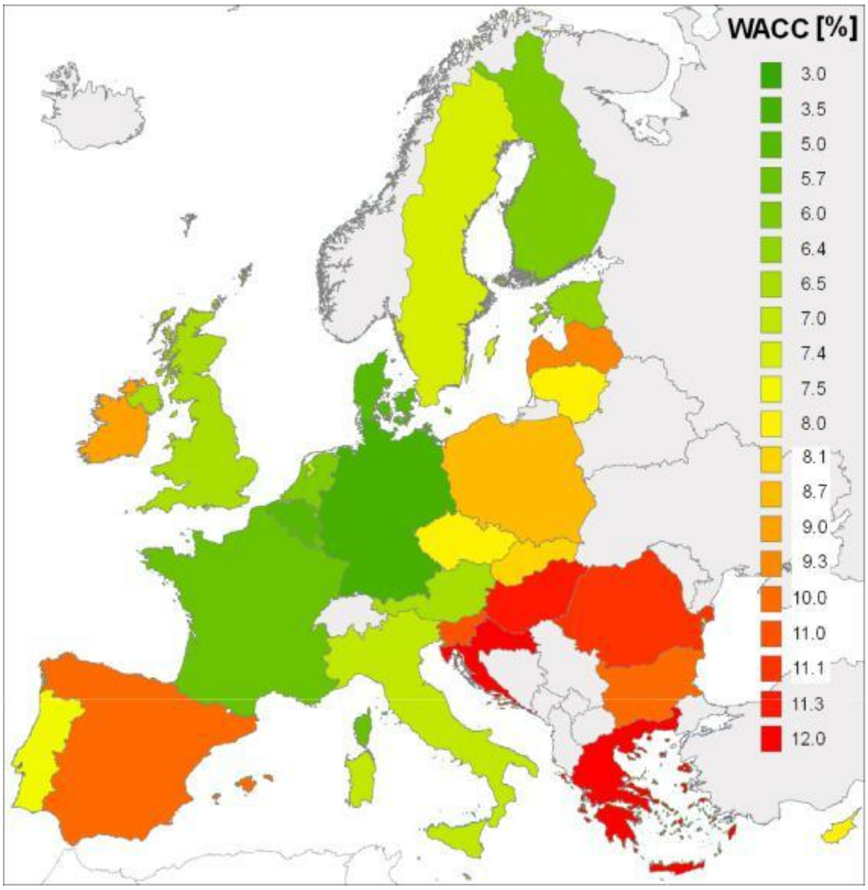


Sources: IEA PVPS, BSW, DoE SunShot Initiative, Eurostat, Solar Choice, OECD key economic data

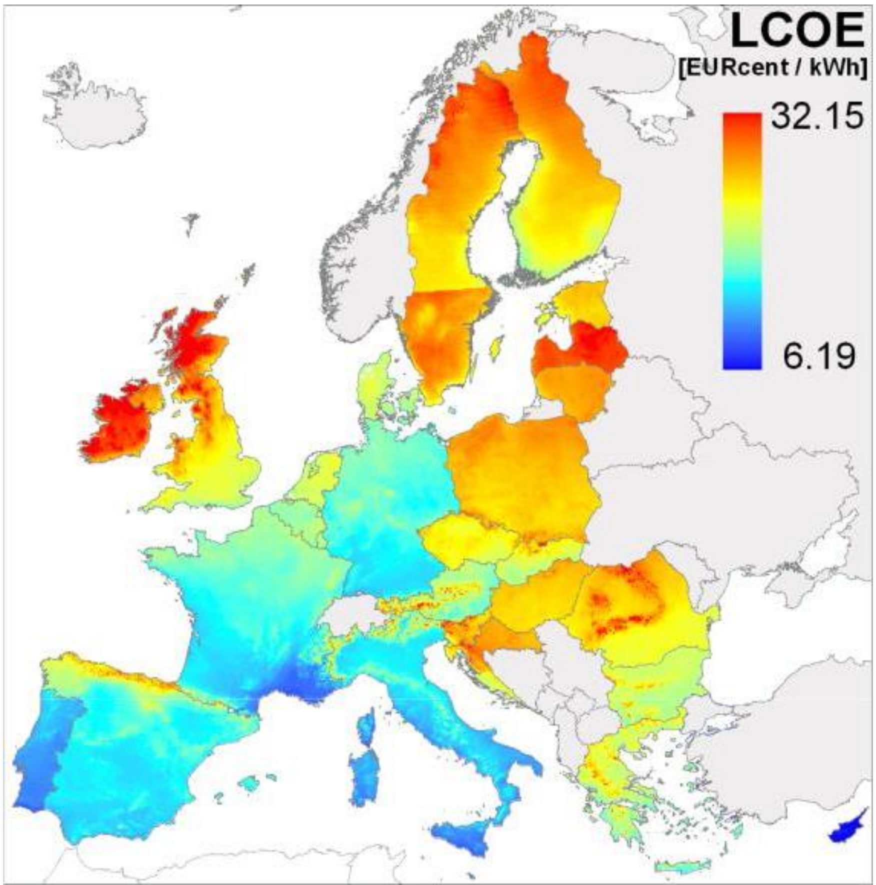
In a recent study location-specific LCOE values were calculated for rooftop PV systems in the European Union (Fig. 13) [Bod 2019]. The different WACC values for new projects, mainly important for commercial projects, are depicted as well.

The used benchmark CAPEX for an installed PV system was EUR 1 100/kWp for all countries. Rooftop systems can be either commercial or private residential investments with only the latter being charged with value-added tax (VAT). VAT values vary significantly between countries and no detailed country statistics are available for the respective shares of commercial and residential systems. Therefore, the study did not consider the additional VAT costs for private systems, which range between 0 and 25% in the Member States of the European Union [EC 2019]. The annual O&M costs were estimated as 3% or EUR 33 per kWp and year. This value is intentionally conservative to reflect the higher O&M of rooftop systems due to their relatively smaller size compared to ground-mounted systems. The electricity generation was calculated for every location using the Photovoltaic Geographical Information System (PVGIS) methodology and then aggregated at country- and EU-level [Hul 2015, 2018].

Figure 13 Map of the WACC and LCOE of rooftop solar PV systems in the EU .



(a): WACC values; source: [Res 2016]



(b): Spatial distribution of the LCOE of rooftop solar PV systems in the EU; source [Bod 2019]

Worldwide, the number of countries, where electricity production from residential PV solar systems can be cheaper than the variable part of residential electricity prices is growing. At the same time the number of countries offering feed-in tariffs or net metering is decreasing. Therefore, using self-generated electricity provides a means to lower the electricity bill on one hand, and to lower and smoothen the influx of PV generated electricity to the grid network. However, the percentage and the economic competitiveness of PV generated electricity very much depends on the actual size of the PV system, the solar radiation at a given location, the amount and load curve as well as at what time the electricity is consumed.

There are in principle two methods, to optimise the direct consumption ('Self-Consumption') of solar electricity. One is to use intelligent behaviour or control systems, which switch major loads (washing/dryer machines, heat pumps, refrigerators, air-conditioners) on when the sun is shining. However, there are limitations to such measures. The second one requires a means to store the energy, either as electricity which requires accumulators, or as 'product', (heat-storage, cold-storage or pumped water), for use at night or rainy days. Storing electricity has the additional advantage of enabling the possibility to offer it to the network operator at times the system owner chooses as being profitable, if such mechanisms are available.

Nevertheless, some fraction of the electricity generated has to be sold to the grid. The question is what kind of pricing should be used — contract, wholesale or day-ahead prices. The fact that the costs of PV-generated electricity can be equal to or lower than residential electricity costs is not yet sufficient to support a self-sustained and unsupported market.

There is a wide range of prices for PV systems as well as electricity for customers in different countries, which defines the attractiveness of self-consumption. The level of overall PV production affects the level of self-consumption and hence the cost of the self-consumed electricity. Other parameters like the base to peak load ratio, or the composition of the electricity portfolio have big impact on the RES levels and network costs. So far, self-consumption in most countries has been limited to the owners or tenants of single family homes or small PV systems in apartment buildings.

Over the last few years, the concept of PV system use in apartment buildings has gained momentum and new economic concepts have been developed to use the electricity from a common PV system for all tenants in such a building. Different concepts, administrative provisions as well as technical regulations end electricity codes for self-consumption in multi apartment buildings exist [Jäg 2019a]. So far the business opportunities are limited due to regulations, not technical requirements.

Energy communities are an additional concept, which was introduced into European legislation by the 2018 recast of the European Renewable Energy Directive (RED II) [EU 2018] and the 2019 recast of the Electricity Market Directive (EMD II) [EU 2019]. RED II defines "Renewable Energy Community" (REC), whereas EMD II talks of "Citizen Energy Community" (CEC). Both concepts are similar, but also have some critical differences. The common element is that both energy communities are set up as a legal person. Their primary objective is to provide environmental, economic and social community benefits rather than financial profits and they have to be controlled by their shareholders or members. The main differences are concerning the geographic location and the allowed activities and technologies. The members of RECs must be located in the proximity of the project, they can only develop renewable energy projects, but in all sectors. On the other hand CECs have no geographic limitations and Member States can even allow cross border activities. In addition the activities of CECs are limited to the electricity sector but not obliged to use renewable energy sources.

3.4 Residential and commercial PV systems with electricity storage models

Some electricity providers in Europe are offering PV systems and local storage to their customers, often including maintenance services. The packages also include apps to monitor the performance of the system, use of electricity and often functionality to control the match between demand and supply. The motivation for this model is described by those companies as follows: 'This gives customers a complete and compatible package consisting of a PV system, storage device, app, and green electricity tariff.' However, no information is given at which rate the company would buy self-generated electricity.

Battery producers and storage system developers have started to offer their customers the organisation of their decentralised electricity generation and storage facilities as virtual power plants and acting as electricity providers and traders. Examples are Sonnen Gmbh (purchased by Siemens in early 2019) or E3/DC.

Another concept is 'virtual storage' for electricity generated by PV systems either for a monthly fee or a down payment for a number of years. To take advantage of this offer, the PV system owner has to be a customer of the respective service provider. The advantage of the virtual storage is that the customer has no installation and maintenance costs for the storage system and virtually infinite lifetime.

In addition, there are a number of companies, which offer the management of swarm or cluster storage facilities in cooperation with distribution network operators. However, detailed business model is still very limited.

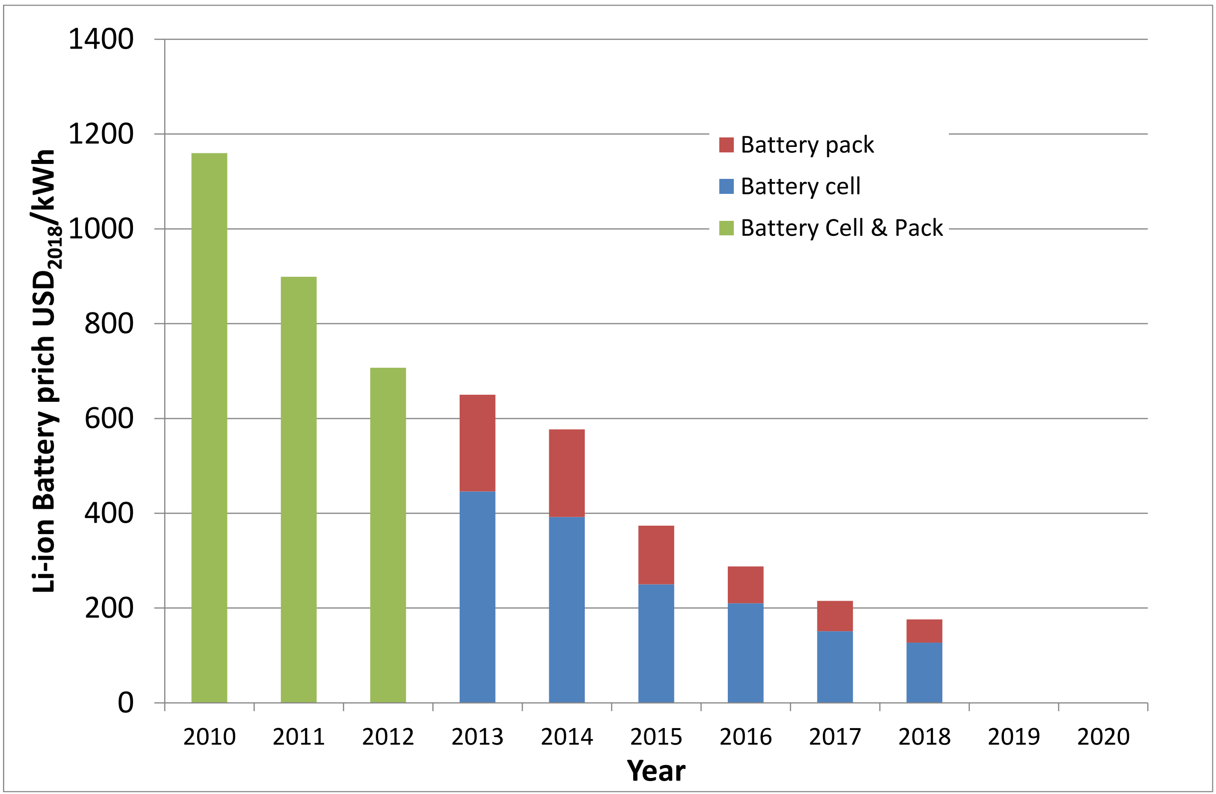
The number of residential and commercial PV system with physical on-site storage is growing with decreasing battery costs. The motivation for both types of customers differs from market to market and whether or not support schemes for the investment in battery systems are available or not. There is a common motivation, to lower the amount of electricity bought from the grid, or in the case of stand-alone systems – generated from the diesel gen set. In addition, commercial customers are in general billed not only for their electricity consumption in kWh but also for the maximum power they draw from the grid in a given time period, even if it is only for a short period of time. The reduction of this maximum power can already be a strong motivation for the installation of a battery system, even without a PV system in place.

The levelised cost of electricity storage is directly correlated with the charge and discharge cycles per given time period. In general, the levelised costs of storage are higher for systems with a lower number of cycles. Therefore, the economic competitiveness of a residential or commercial storage systems depend very much on the individual situation.

As with PV modules in solar photovoltaic systems, battery costs are only a part of the total storage system, but the steep price reduction indicates the fast development of the sector. Between 2010 and 2018, prices for battery packs have decreased by almost 85% (Fig. 14) [Blo 2019c]. Another important cost factor is the control electronics needed to combine the storage with a PV system and the grid. Currently, this part remains a significant factor, but can be integrated into the inverter and will come down in price when the production volume increases. At the moment residential PV systems with storage are still more than twice as expensive as PV systems without storage. On the other hand, in terms of size, electricity storage systems for PV systems can be compared with the PV market situation of about 10 to 12 years ago.

At the end of 2018 the fully commissioned battery manufacturing capacity worldwide was 367 GWh. Factories with another 346 GWh were under construction and another 525 GWh announced to become operational until 2023.

Figure 14: Battery pack price development over the last decade

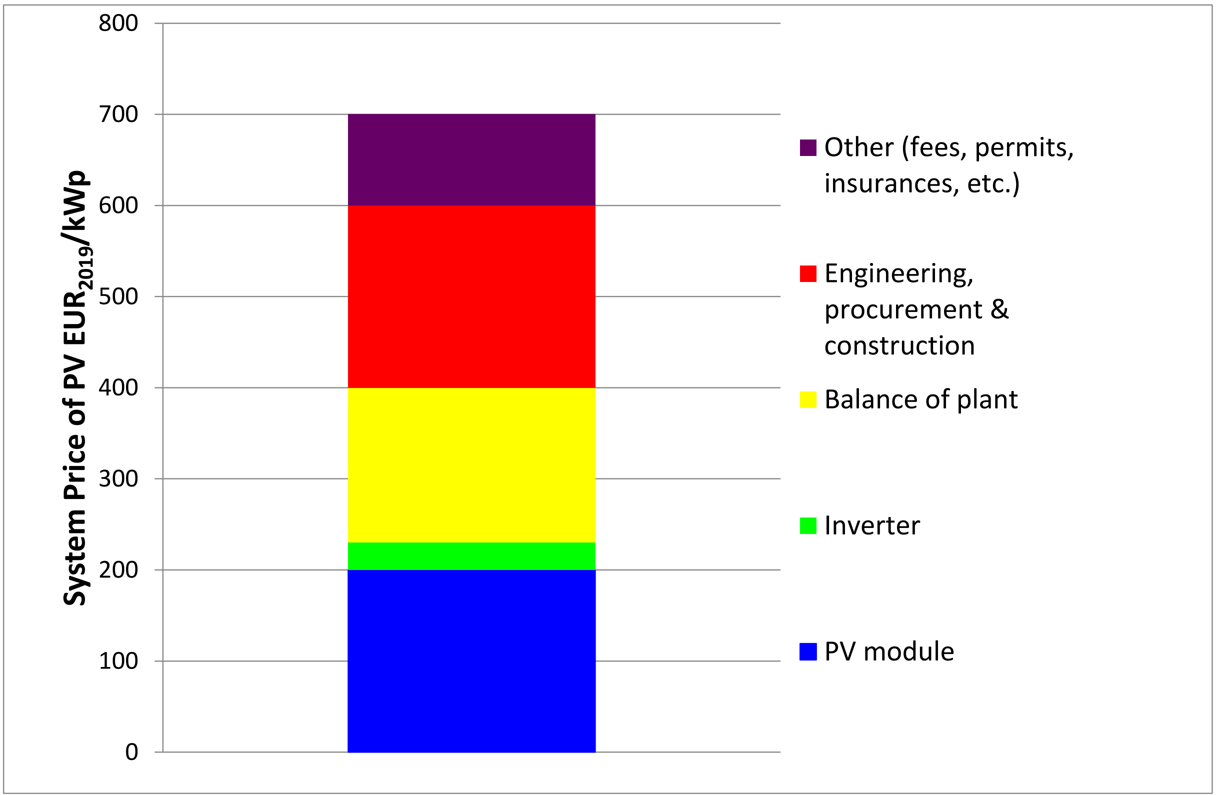


3.5 LCOE of utility-scale PV systems

Utility-scale PV systems can be defined as a PV system larger than 10 MW. The first such system was installed in 2006 after the 2004 revision of the German EEG, which for the first time made such systems eligible for a FiT. The first boom occurred in 2008, triggered by the Spanish FiT, when almost 1 GW was installed. When the Spanish bubble burst, the volume dropped to less than 500 MW in 2009, before activities picked up again in 2010. At the end of 2015, about 65 GW of utility-scale PV power plants were operational worldwide and this mark could increase sevenfold by the end of 2020.

Due to the plant size, which is currently up to 2 GW_{AC}[36], the cost structure and LCOE is quite different from that of residential PV systems. Figure 15 shows an average cost breakdown in competitive markets. The actual cost breakdown can differ from project to project.

Figure 15: Price breakdown of utility-scale PV system



For the first time, a number of record breaking PPA contracts and bids below USD 30/MWh were reported in 2016. The first bids below USD 20/MWh followed in 2019 in the USA (USD 19.97/MWh), Mexico (USD 19.7/MWh), Brazil (USD 17.5/MWh) and Portugal (EUR 14.5/MWh). It should be noted that the project in Los Angeles, USA, is for a 400 MW_{AC} solar plant with up to 200 MW/800 MWh of energy storage at USD 13.00/MWh. The offer was accepted by the Los Angeles City Council in early September [Los 2019].

As already mentioned, these very low bids and are only possible through a combination of excellent solar resource with high load factors, high debt shares and very low debt costs as well as the fact that some tariffs are indexed to inflation. The plants have to become operational within the next three to five years.

According to IRENA, 53.2 GWAC of solar photovoltaic power was auctioned between January 2017 and December 2018 [Ire 2019]. This corresponded to 55% of renewable power auctioned during this time span. The largest share was auctioned in South-East Asia

A[36] Benban solar complex, Egypt

(>24 GW_{AC}), followed by Europe (>12 GW_{AC}) and Africa (7.9 GW_{AC}). The average global price average of PV auctions has declined from USD 89/MWh in 2016 to USD 52/MWh in 2018 [IEA 2018].

However, PPAs do only reflect partly the actual economic competitiveness of a solar project. When comparing it to other projects, it is also important to know what the tax regime for such a project or competing power projects have, e.g. in the USA PV projects qualify for the federal energy ITC programme (30 %) and the Modified Accelerated Cost Recovery System depreciation (five-year MACRS). The ITC is 30 % until 2019 then it is reduced to 26 % in 2020 and 22 % 2021. After 2023, the residential credit will drop to zero while the commercial and utility credit will drop to a permanent 10 %.

4 CONCLUSIONS AND OUTLOOK

Despite a significant market reduction in China, caused by the end of the feed-in tariff in June 2018, the new installed capacity of solar PV power increased worldwide by 7% to about 107 GW, despite a 22% annual investment decline.

For the 9th year in a row, solar power attracted the largest share of new investments in renewable energies [Blo 2019]. The USD 140 billion (EUR 122 billion) investments in solar energy, accounted for 42.5 % of all new renewable energy investments.

Governmental and industrial R&D spending increased by almost 19% from USD 11.8 billion (EUR 10.3 billion) to USD 14 billion (EUR 12.2 billion [Ren 2019]. Despite the urgency to accelerate the energy transition this corresponds to only 11.5% of the overall energy R&D expenditures of USD 121 billion (EUR 105 billion) [IEA 2019a].

The trend that the developing economies invest more in renewable energy capacity than the developed ones continued for the fourth year. Out of the USD 140 billion (EUR 122 billion) investments in solar energy, 54% or USD 75 billion (EUR 65 billion) were invested in developing economies.

The PV industry has changed dramatically over the last few years. China has become the major manufacturing country for solar cells and modules, followed by Taiwan and Malaysia.

If Europe wants to half its GHG emissions by 2030 a rapid decarbonisation of its power sector by 80% is necessary. To achieve this an additional PV capacity of between 75 and 350 GW, leading to a total capacity of up to 825 GW, over a business as usual scenario would be needed in the EU by 2030 [Jäg 2019]. Such an increase in solar PV capacity would require an EU market growth from about 14 GW in 2019 to 70 GW or more in 2030. At current, the production capacity for solar cells and solar modules in the European Union is just 1 GW and 3 GW respectively. From a supply security point of view the massive increase of installations should therefore be matched by a realistic regional production in the Union to avoid supply disruptions.

Recent rapid cost reduction in PV manufacturing and the additional capacities required merit a fresh look at the potential to bring PV factories back to Europe. Specific investment costs required for PV cell and module manufacturing plants have decreased by approximately 90% during the last ten years. A recent study by the Fraunhofer Institute for Solar Research (Fh ISE) commissioned by the German Mechanical Engineering Industry Association (VDMA) has shown that an European Manufacturing Chain could be competitive if solar factories with a production volume between 5 and 10 GW per annum can be realised [Vdm 2019].

In 1990, implementation of the 100 000 roofs programme in Germany, and the Japanese long-term strategy set in 1994, with a 2010 horizon, marked the beginning of extraordinary growth in the PV market. Before the start of the Japanese market implementation programme in 1997, annual growth rates were about 10 % in PV markets, driven mainly by communication, industrial and stand-alone systems. Since 1990, PV production has increased by three orders of magnitudes, from 46 MW to over 100 GW in 2017. This corresponds to a CAGR of more than 40 %. In 2018, statistically documented cumulative installations worldwide accounted for almost 520 GW.

Driven by the continuation of lower generation cost of solar photovoltaic power, the number and volume of new PV markets worldwide is increasing. A growing number of large investors are steadily increasing their investments in renewable energy and solar PV, like Warren Buffet, or even de-investing in fossil energy companies and shifting this investment to renewable energy, as already announced by the Rockefeller Brother Fund before the UN Climate Summit 2014 [BBC 2014].

With respect to the future market development of renewable power and solar photovoltaics in particular, the formal launch of an alliance of nations and states committed to moving the world from burning coal to cleaner power sources was a promising sign at COP23 in Bonn 2017. In their founding declaration, the Powering Past Coal Alliance states: "To meet the Paris Agreement, analysis shows that coal phase-out is needed no later than by 2030 in the OECD and EU28, and no later than by 2050 in the rest of the world" [Ppc 2017]. In October 2019, the Alliance had 91 members representing 32 national governments, 25 sub-national governments, and 34 businesses or organisations.

Alongside the overall rising energy prices and the need to stabilise the climate, this will continue to keep the demand for solar-power systems high. In the long term, growth rates for PV will continue to be high, even if economic conditions vary locally and lead to a short-term downturn in some of the markets.

This view is shared by an increasing number of financial institutions, which are turning to renewables as a sustainable and stable long-term investment. Even if the oil prices have retreated from their record highs in 2008, when they were close to USD 150/bbl, their volatility, possible by supply disruptions caused by political uncertainties or natural disasters is causing an economic risk.

In addition, the fact that the Paris Agreement entered into force on 4 November 2016 gives an additional impetus to decarbonise our electricity supply and attracts additional investments in renewable and in particular PV power [UNFC 2016].

Since 2010 various studies about subsidies for combustibles, fuels and electricity were published [see ref in Jäg 2018]. A 2019 working paper of the International Monetary Fund (IMF) showed that these post-tax subsidies were increasing from USD 3.6 to 5.2 trillion or 5.4 to 6.5% of GDP between 2010 and 2017 [IMF 2019]. Over 95% of these subsidies went to coal, petroleum and natural gas. These figures more than 10 times the amount the IEA presents in the World Energy Outlook 2019 as direct subsidies for fossil fuels (USD 319 billion in 2017) [IEA 2019c].

As early as 2010, the Financial Times cited Fatih Birol, then Chief Economist at the IEA in Paris, saying that removing subsidies was a policy that could change the energy game 'quickly and substantially'. 'I see fossil fuel subsidies as the appendicitis of the global energy system which needs to be removed for a healthy, sustainable development future,' he told the newspaper [FiT 2010].

This was in line with the findings of a 2008 UNEP report Reforming Energy Subsidies [UNEP 2008], which concluded: 'Energy subsidies have important implications for climate change and sustainable development more generally through their effects on the level and composition of energy produced and used. For example, a subsidy that ultimately lowers the price of a given fuel to end-users would normally boost demand for that fuel and the overall use of energy. This can bring social benefits where access to affordable energy or employment in a domestic industry is an issue, but may also carry economic and environmental costs. Subsidies that encourage the use of fossil fuels often harm the environment through higher emissions of noxious and greenhouse gases. Subsidies that promote the use of renewable energy and energy-efficient technologies may, on the other hand, help to reduce emissions.'

In the Energy Technology Perspectives (ETP) 2017 the IEA states that "The investment costs associated with the 2DS across the power, buildings and transport sectors, and within the energy-intensive industries, would not require unreasonable additional financial contributions from the global economy" [IEA 2017]. According to the ETS, the shift from a 2 °C scenario (2DS) to a 1.75 °C scenario (B2DS) in order to fulfil the pledge of the Paris Agreement, would require a full decarbonisation of the power sector well before 2050.

The 2010 to 2017 energy subsidies sum up to roughly USD 31 trillion and would have been sufficient to more than finance the investments in the power sector to realise the B2DS, which would require USD 23 trillion (EUR 19.2 billion) or 0.2% of the cumulative global GDP between 2017 and 2060 compared to USD 16.7 trillion (EUR 13.92 trillion) (0.15% GDP) for the 2DS.

Following the massive cost reductions for the technical components of PV systems, like modules, inverters, BOS, etc., the still existing challenge is to lower the soft costs of PV system installations, such as the permits and financing costs. Despite the fact that PV system components are global commodity products, the actual prices for installed PV systems vary significantly. In the third quarter of 2019, the average system price for residential systems was about AUD 1.03/Wp (EUR 0.65/Wp), in Australia, but around USD 3.30 (EUR 3.00/kWp) in the USA and JPY 240/kWp (EUR 2.00/kWp) in Japan [Blo 2019a, Ikk 2019, Sol 2019a]. Competition and an increasing number of experienced installers are bringing costs further down.

In some countries, like Germany or Italy, the installed PV capacity already exceeds 30 % and 20 % of the installed thermal power plant capacities, respectively. Together with the respective wind capacities, wind and solar together will exceed 60 % and 30 %, respectively. To handle these high shares of renewable electricity, new technical and regulatory solutions have to be implemented to avoid running into the problem of curtailing large parts of this electricity.

Besides conventional pumped storage options, electrical batteries are becoming increasingly interesting, especially for small-scale storage solutions in the low-voltage distribution grid. According to BNEF, prices for battery packs have declined by 85% between 2010 and 2018 [Blo 2019c]. By 2025, the battery pack prices could fall below USD 100/kWh. Lithium-ion batteries have an average of 5 000 cycles, and with the above cost estimates, this could enable levelised costs of electricity storage below USD 0.05/kWh (EUR 0.045/kWh) by 2025.

As early as February 2012, BYD (Build your Dreams) and the State Grid Corporation of China (SGCC) finished the construction of a large-scale utility project located in Zhangbei, Hebei Province, which combines 100 MW of wind power, 40 MW of solar PV electricity system, and 36 MWh of lithium-ion energy storage. It is interesting to note that the batteries used in this system are lithium-ion car batteries, which were used before in the BYD 36 taxi for about 4 000 cycles [Che 2014]. Larger PV plants > 50 MW with up to 4h of partial storage are already very common.

According to investment analysts and industry prognoses, solar energy will continue to grow at high rates in the coming years. The different PV industry associations, as well as Greenpeace, the European Renewable Energy Council (EREC), the Energy Watch Group with Lappeenranta University of Technology (LUT), Bloomberg New Energy Finance (BNEF), the International Energy Agency and the International Renewable Enregy Agency (IRENA), have developed scenarios for the future growth of PV systems [Blo 2019d, Gre 2015, IEA 2016, 2018, Ire 2019a, Ram 2017, 19]. Table 1 shows the different scenarios of the Greenpeace/EREC study, the Energy Watch Group/LUT studies, BNEF New Energy Outlook (NEO) 2019 and the 2016 and 2018 IEA World Energy Outlook scenarios. It is interesting to note that the predicted PV capacity in the IEA scenarios has significantly increased from 2016 to 2018 but are still at the lower end. Older scenarios can be found in the previous PV Status Reports [Jäg 2013, 14].

With forecasted world-wide new installations between 230 and 295 GW in 2019 and 2020, even the 100% RES Power Sector scenario for 2020 is within reach [Blo2019a].

These projections show that there are huge opportunities for PV in the future if the right policy measures are taken, but we have to bear in mind that such a development will not happen by itself. It will require the sustained effort and support of all stakeholders to implement the envisaged change to a sustainable energy supply with PV delivering a major part. The main barriers to such developments are perception, regulatory frameworks and the limitations of the existing electricity transmission and distribution structures. In view of the urgency to decarbonise our energy and power supply much faster than thought only a few years ago, the actual growth of the PV markets is not in line with needs for such a transition.

Due to the long lifetime of conventional power plants (30 to 50 years), the still ongoing huge investment in new fossil power plants will influence key socioeconomic and ecological factors in our energy system in 2030 and beyond.

Table 1: Evolution scenarios of the world-wide cumulative solar electrical capacities until 2040

Year	2018 [GW]	2020 [GW]	2025 [GW]	2030 [GW]	2040 [GW]
Actual Installations	**520**				
Greenpeace (advanced [r]evolution scenario)		844	2 000	3 725	6 678
LUT 100% RES Power 2017		1 168	3 513	6 980	13 805
LUT 100% Energy 2019		1 097	1 628	12 951	30 531
BNEF NEO 2019		795	1 435	2 440	5 044
IRENA 2019 reference case*		514	1 020	2 017	3 122
IRENA 2019 REmap case*		583	1 358	3 151	5 761
IEA New Policy Scenario 2016		481	715	949	1 405
IEA 450ppm Scenario 2016**		517	814	1 278	2 108
IEA New Policy Scenario 2018**		665	1 109	1 589	2 540
IEA Sustainable Development Scenario 2018**		750	1 472	2 346	4 240

*: 2020 and 2025 values are interpolated, as only 2016 and 2030 values are given
**:2025 value is interpolated, as only 2020 and 2030 values are given

The solar PV scenarios shown above will only be possible if solar cell and module manufacturing are continuously improved and novel design concepts are realised, since the current technology's demand for certain materials, like silver, would dramatically increase the economic costs of this resource within the next 30 years. Research to avoid such problems is under way and it is expected that such bottlenecks will be avoided.

The PV industry is moving closer to a mass-producing industry with 20^{+}GW production companies. This development is linked to increasing industry consolidation, which presents both a risk and an opportunity at the same time. If the new large solar-cell companies use their cost advantages to offer products with a power output guaranteed for over 30 years, and at reasonable prices, then PV markets will continue their accelerated growth. This development will influence the competitiveness of smaller and medium-sized companies as well. To survive the price pressure of the very competitive commodity mass market, and to compensate for the advantages enjoyed by big companies through the economies of scale that come with large production volumes, smaller businesses will have to specialise in niche markets offering products with high value added or special solutions tailor-made for customers. The other possibility is to offer technologically more advanced and cheaper solar-cell concepts.

The global world market, dominated by Europe in the last decade, has rapidly changed into an Asia dominated market. The internationalisation of the production industry is mainly due to the rapidly growing PV manufacturers from China and Taiwan, as well as new market entrants from companies located in India, Malaysia, the Philippines, Singapore, South Korea, UAE, etc. At the moment, it is hard to predict how the market entrance of new players worldwide will influence future developments in the manufacturing industry and markets.

Over the last 10 years, not only have we observed a continuous rise in energy prices, but also a greater volatility. This highlights the vulnerability created by our current dependence on fossil energy sources, and increases the burden developing countries are facing in their struggle for future development. On the other hand, we are seeing a continuous fall in production costs for renewable energy technologies and the resulting LCOE, as a result of industry learning curves.

It is important to remember that only parts of the LCOE of PV electricity comes from the overnight investment costs. Since external energy costs, subsidies in conventional energies and price volatility risks are not generally taken into account, renewable energies and PV are still perceived as being less mature in the market than conventional energy sources and have to pay extra risk premiums for their financing. In the mean-time, financing, permits and administrative costs are much more relevant for the final costs of PV electricity. If access to financing was on the same level, LCOE costs could decrease considerably. Nevertheless, electricity production from PV solar systems has already proved that it can be cheaper than residential consumer prices in a wide range of countries. In addition, in contrast to conventional energy sources, renewable energies are still the only ones to offer the prospect of a reduction rather than an increase in prices in the future.

References

[Acw 2015] ACWA Power, Press Release, 15 July 2015, ACWA Power led consortium achieves financial close for the landmark Shuaa Energy 1-260 MWp Solar PV IPP transaction (Phase II of Dubai Electricity and Water Authority's Mohammed bin Rashid Solar Park in Dubai)

[ADB 2014] Asia Development Bank, Scoping off-grid renewable energy opportunities in Myanmar, March 2014

[Adm 2019] ΛΕΙΤΟΥΡΓΟΣ ΑΓΟΡΑΣ ΗΛΕΚΤΡΙΚΗΣ ΕΝΕΡΓΕΙΑΣ Α.Ε. (Greek Operator of the Electricity Market -ADMIE), Συνοπτικὁ Πληροφοριακὁ Δελτἰο - Μἀρτιος 2018, http://www.lagie.gr/fileadmin/groups/EDRETH/RES/DELTIO_APE_MARTIOS_2019.pdf

[Ago 2019] Agora Energiewende and Sandbag (2019): The European Power sector in 2018. State of Affairs and Review of Current Developments, 150/03-A-2019/EN

[Alt 2019] Alternative Energy Development Board, Ministry of Water & Power, Government of Pakistan, http://www.aedb.org/index.php/ae-technologies/solar-power/solar-current-status, accessed 13 September 2019

[Amp 2019] AMPERE, Press reléase 27 February 2019, http://www.ampere-h2020.eu/news/amperes-first-hjt-solar-cell

[Ase 2016] Autoridad Nacional de los Servicios Públicos (ASEP), Press Release, 15 April 2016, ASEP considera ampliar capacidad de instalación de energía solar en hogares y comercios del país

[Ase 2018] Autoridad Nacional de los Servicios Públicos (ASEP), Panama, Estadísticas año 2018 II Semestre 2018, https://www.asep.gob.pa/?page_id=12613

[BBC 2014] BBC, Rockefellers to switch investments to 'clean energy', 23 September 2014, http://www.bbc.com/news/world-us-canada-29310475

[BGB 2017] Bundesgesetzblatt für die Republik Österreich, Jahrgang 2017 Ausgegeben am 26. Juli 2017, Teil I;108. Bundesgesetz: Änderung des Ökostromgesetzes 2012, des Elektrizitätswirtschafts- und -organisationsgesetzes 2010, des Gaswirtschaftsgesetzes 2011, des KWK-Punkte-Gesetzes und des Energie-Control-Gesetzes sowie Bundesgesetz, mit dem zusätzliche Mittel aus von der Energie-Control Austria verwalteten Sondervermögen bereit gestellt werden

[Bet 2019] Better Energy, Press Release 13 February 2019, https://www.betterenergy.com/news/heartland-and-better-energy-announce-subsidy-free-solar-power-plant/

[Bfe 2019] Schweizer Bundesamt für Energie (Swiss Federal Office for Energy), Schweizerische Statistik der erneuerbaren Energien, Ausgabe 2018, Juni 2019

[Bis 2014] BISOL, Press Release, 29 January 2014

[Blo 2013] BNEF, Scaling up financing to expand the renewables portfolio, Presentation given by Michael Liebreich (CEO) at the IEA Renewable Energy Working Party, Paris 9 April 2013

[Blo 2019] Bloomberg New Energy Finance, Clean Energy Investment Trends, 1H 2019, 10 July 2019

[Blo 2019a] Bloomberg New Energy Finance, 3Q 2019 Global PV Market Outlook, 27 August 2019

[Blo 2019b] Bloomberg New Energy Finance, 1H 2019 LCOE Update, 26 March 2019

[Blo 2019c] Bloomberg New Energy Finance, A Behind the Scenes Take on Lithium-ion Battery Prices, 5 March 2019, https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

[Blo 2019d] Bloomberg New Energy Finance, New Energy Outlook 2019, June 2019

[BKV 2018] Doc 542883/001, Kamer R 5e Zitting van de 54e Zittingsperiode, 2017/2018, Belgische Kamer van Volksvertegenwoordigers, Voorstel van Resolutie over het Belgisch Interfederaal Energiepact, 11 januari 2018, http://www.lachambre.be/FLWB/PDF/54/2883/54K2883001.pdf

[Bna 2016] Bundesnetzagentur (Federal Grid Agency, Germany), Press Release, 28 November 2016

[Bna 2019] Bundesnetzagentur (Federal Grid Agency, Germany), EEG Registerdaten und Fördersätze

[Bod 2019] Katalin Bódis, Ioannis Kougias , Arnulf Jäger-Waldau, Nigel Taylor, Sándor Szabó, A high-resolution geospatial assessment of the rooftop solar photovoltaic potential in the European Union, Renewable and Sustainable Energy Reviews, Volume 114, October 2019, 109309, https://doi.org/10.1016/j.rser.2019.109309

[Bri 2019] Bridge to India, India Solar Compass Q2 2019, August 2019

[Cai 2015] Caixin, 1 September 2015, 5年再造个国家电网，2万亿配网投资你真看懂了吗？, http://www.wusuobuneng.com/archives/23118

[Cbs 2019] Centraal Bureau voor de Statistiek, Hernieuwbare elektriciteit; productie en vermogen, 27 June 2019, http://statline.cbs.nl

[Cec 2019] 中国电力企业联合会 (China Electricity Council), 可再生能源发展已远超规划 (Renewable energy development has far exceeded planning), 14 March 2019, http://www.cec.org.cn/xinwenpingxi/2019-03-14/189501.html

[Cep 2019] China Energy Policy Newsletter: March 2019, https://www.energypartnership.cn/fileadmin/user_upload/china/media_elements/newsletter/CNREC_Newsletter_EN/China_Energy_Policy_Newsletter_March_2019.pdf, accessed 15 Septemer 2019

[Che 2014] Robert Chen, BYD Motors, PRC, private communication

[CNC 2016] Centro Nacional de Control de Energía, Comunicado conclusión 1ª Subasta Eléctrica de Largo Plazo, 30 March 2016

[CNC 2016a] Centro Nacional de Control de Energía, Inversión de 4 mil millones de dólares al concluir el proceso de la Segunda Subasta Eléctrica, 28 September 2016

[CNE 2019] Comisión National de Energía, Chile, Capacidad Instalada Generación, Julio de 2018 https://www.cne.cl/en/estadisticas/electricidad/

[CNM 2017] Comisión Nacional de los Mercados y la Competencia, Notas de Prensa, 5 Abril 2017, La CNMC publica dos informes sobre el estado actual de la deuda del sistema eléctrico y gasista

[Col 2018] Finlay Colville, PV-Tech, 13 February 2018, PV capex to exceed US$10 billion in 2018, with 25% growth forecast https://www.pv-tech.org/editors-blog/pv-capex-to-exceed-us10-billion-in-2018-with-25-growth-forecast

[Com 2016] Commission de Régulation du Secteur de l'Electricité, Avis de Pre-Qualification pur la Selection de Producteurs Indeoendants d'Electricite por la Mise en Place de Centrales Solaires Photovoltaïques dúne Capacite Cumulee d'Environ 100MWc, http://www.scalingsolar.org/wp-content/uploads/2016/08/crse-avis.pdf, accessed 14 Septembre 2017

[Dai 2019] Daily News Egypt, تشغيل 27 محطة شمسية فى مجمع «بنبان» بقدرات إجمالية 1200 ميجاوات, 24 July 2019, https://alborsaanews.com/2019/07/24/1227763

[DGE 2019] Direção Geral de Energia e Geologia (DGEG), Press Release 07 August 2019, Resultados finais do procedimento concorrencial, sob a forma de leilão eletrónico, para atribuição de reserva de capacidade de injeção na rede elétrica de serviço público para energia solar fotovoltaica http://www.dgeg.gov.pt/

[Dha 2017] Dhaka Times, Cabinet okays 258 MW solar power plant projects, 1 March 2017

[Dir 2019] Direção-Geral de Energia e Geologia, renováveis, Estatística rapidas – no 174 – abril de 2019

[EC 2017] European Commission, State Aid SA.44076 – Hungary Aid for electricity production from renewable energy sources (METÁR), 11.07.2017, C(2017) 4988 final

[EC 2018] European Commission Communication, A Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, COM(2018) 773 final, 28.11.2018

[EC 2018a] In-Depth Analysis in Support of the Commission Communication COM(2018) 773 A Clean Planet for all - A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf

[EC 2018b] European Commission – Press release, State aid: Commission approves three support measures for renewable energy in Denmark, IP/18/5042,http://europa.eu/rapid/press-release_IP-18-5042_en.htm

[EC 2018c] European Commission – Press release, IP/18/5461, State aid: Commission approves Greek auction scheme for renewable electricity, 4 January 2018, europa.eu/rapid/press-release_IP-18-5461_en.pdf

[EC 2019] European Commission , Taxud.c.1(2019) – EN, VAT rates applied in the Member States of the European Union - Situation at 1st January 2019; https://ec.europa.eu/taxation_customs/sites/taxation/files/resources/documents/taxation/vat/how_vat_works/rates/vat_rates_en.pdf

[Ecr 2016] ECREE, ECOWAS observatory for renewable energy and energy efficiency, Project: Oyandze

[EEG 2000] Gesetz über den Vorrang erneuerbaren Energien (Erneuerbare-Energien-Gesetz — EEG), Bundesgesetzblatt Jahrgang 2000, Teil I, No 13, p. 305, 29 March 2000

[EEG 2014] Gesetz für den Ausbau erneuerbarer Energien (Erneuerbare-Energien-Gesetz — EEG 2014) Bundesgesetzblatt Jahrgang 2014, Teil I, No 33, 24 July 2014, p. 1066

[Ega 2019] Renate Egan, National Survey Report of PV Power Applications in Australia 2018, International Energy Agency PVPS Task1, PV in Australia Report 2018, Australian PV Institute, August 2019

[Ega 2019a] Electricity Generating Authority of Thailand, EGAT invites sealed bids of Floating Solar Power Plant for Sirindhorn Dam Hydro-Floating Solar Hybrid Pilot Project, 13 June 2019, http://www4.egat.co.th/fprocurement/biddingeng//uploads/EGAT_6_2561-SRD-FPV.pdf

[EIB 2018] European Investment Bank, EIB to support solar project in Zambia, Press release 20 June 2018

[EIB 2018a] European Investment Bank, Radiant and Eldosol Solar Power Plants Project fiche, accessed September 2019, https://www.eib.org/en/projects/pipelines/all/20150682

[Eli 2017] elia, Electricity Scenarios for Belgium towards 2050, November 2017, http://www.elia.be/~/media/files/Elia/About-Elia/Studies/20171114_ELIA_4584_AdequacyScenario.pdf

[EMA 2019] Government of Singapore, Energy Market Authority, Installed capacity of grid-connected solar photovoltaic (PV) systems, data from 20 September 2019

[Ena 2016] Ethiopian News Agency, 28 August 2016, EEP to transfer solar energy projects to private developers

[Ene 2016] Energistyrelsen (Danish Energy Agency), Press Release, 12 December 2016

[Ene 2017] Enel, Press release, 23 October 2017

[Ene 2018a] Energistyrelsen (Danish Energy Agency), 2 May 2018 https://ens.dk/en/our-services/current-tenders/tender-scheme-solar-pv-installed-capacity-less-1-mw, https://ens.dk/en/our-services/current-tenders/tender-scheme-wind-and-solar-pv-2018-2019

[Ene 2018b] Energistyrelsen (Danish Energy Agency), 3 December 2018, https://ens.dk/sites/ens.dk/files/Udbud_aktuelle/faktaark_-_afgoerelse_af_teknologineutralt_udbud_2018.pdf

[Ene 2018c] Enel Green Power, Press Release, 20 March 2018

[Ene 2018d] Enel Green Power, Press Release, 27 September 2018

[Ene 2018e] Enel, Press Release, 21 March 2018

[Ene 2019] Enerdata, Global Energy Statistical Yearbook 2019

[Ene 2019a] Enel Green Power, Press Release, 29 April 2019

[Ene 2019b] Energy for Growth Hub, How to resolve the tariff disputes blocking Nigeria's solar project pipeline?, 20 February 2019, accessed September 2019, https://www.energyforgrowth.org/memo/how-to-resolve-the-tariff-disputes-blocking-nigerias-solar-project-pipeline/

[EP 2016] European Parliament, Committee on Industry, Research and Energy. Report on delivering A New Deal for energy consumers, April 2016

[EPD 2019] Turkish Energy Market Regulatory Authority (EPDK), May 2019, http://www.resmigazete.gov.tr/eskiler/2019/05/20190512-1.htm

[Era 2014] Electricity Regulatory Authority (ERA) of Uganda, 2014 https://www.era.or.ug/index.php?option=com_content&view=article&id=214:renewable-energy-opportunities&catid=100:renewable-energy-investment-guide

[Ern 2017] Ernst & Young, EY Energy Alert, Mexico's 3rd Long Term Power auction, November 2017

[Ete 2015] ETESA, Resolución No GC-01-2015, 28 January 2015

[Eth 2015] The Ethiopian Herald, 24 September 2015, Ethiopia: solar panel factory due to begin production

[EU 2018] Directive (EU) 2018/2001 of the European Pariament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast), Official Journal of the European Union, L 328/82, 21.12.2018

[EU 2019] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market in electricity (recast), Official Journal of the European Union, L 158/125, 14 June 2019

[Eur 2018] Europa Press, Moody's prevé que la deuda del sistema eléctrico español se reduzca en 2018 hasta los 19.000 millones, 11 April 2018

[Ezs 2016] Energie Zukunft Schweiz, Juni 2016, PV-Preisumfrage 2015

[Faa 2018] La Fédération Atlantique des Agences de Presse Africaines (FAAPA), President Commissions 20MW Onyadze Solar power plant, 16 September 2018, http://www.faapa.info/president-commissions-20mw-onyadze-solar-power-plant/

[FiT 2010] *Financial Times*, IEA counts $ 550 billion energy support bill, 6 June 2010 https://www.ft.com/content/27c0ff92-7192-11df-8eec-00144feabdc0

[Fss 2018] F&S Solar, Press release, 19 July 2018

[Get 2017] Global Energy Transfer for Feed–in–Tariffs (GET-FiT) Programme, Annual Report 2017
https://www.getfit-uganda.org/downloads/

[GoA 2006] Ley 26.190 — Ley de Energía Eléctrica (2006), Boletín Oficial de la República de Argentina, Núm. 31.064,
http://www.diputados-catamarca.gov.ar/ley/BO020107.PDF

[GoA 2015] Ley 27191 – Energía Eléctrica Ley N° 26.190 – Su Modification, Boletín Oficial de la República de Argentina, 21-oct-2015, Número: 33239, Página: 1
http://servicios.infoleg.gob.ar/infolegInternet/verNorma.do?id=253626

[GoA 2016] Decreto 531/16 – Régimen De Fomento Nacional Para El Uso De Fuentes Renovables De Energía Destinada A La Producción De Energía Eléctrica, Boletín Oficial del 31-mar-2016, Número: 33347, Página: 2
http://servicios.infoleg.gob.ar/infolegInternet/verNorma.do?id=259883

[GoA 2016a] Decreto 882/2016, Establécese Cupo Fiscal para el Ejercicio 2016,
Boletín Oficial del 22-jul-2016, Número: 33424, Página: 11,
http://servicios.infoleg.gob.ar/infolegInternet/verNorma.do?id=263690

[GoA 2018] Bundesministerium für Nachhaltigkeit und Tourismus und Bundesministerium für Verkehr, Innovation und Technologie, Juni 2018, mission 2030, Die österreichische Klima- und Energiestrategie, https://mission2030.info/wp-content/uploads/2018/06/Klima-Energiestrategie.pdf

[GoC 2015] Government of Chile, Ministry of Energy, Energy 2050 — Chile's energy policy, http://www.energia2050.cl/uploads/libros/energy2050.pdf

[GoC 2018] Government of Cape Verde, 2018 – 2040 Master Plan for the Electricity Sector, 2018, https://peds.gov.cv/caboverdef4dev/wp-content/uploads/2018/12/Ennergy-Sector-web.pdf

[GoD 2007] Ley No 57-07 sobre Incentivo al Desarrollo de Fuentes Renovables de Energía y de sus Regímenes Especiales (Dominican Republic)

[GoG 2013] Gobierno de Guatemala, Ministeria de Energía y Minas, Política Energética 2013 – 2027

[GoH 2014] Decreta No 404-2013: Ley general de la industria eléctrica, La Gazeta, Martes 20 de mayo del 2014, Num. 33 431

[GoH 2018] Gobierno de la República Honduras, Empresa National de Energía Eléctrica (ENEE), Boletín de Datos Estadísticos Diciembre 2018,
http://www.enee.hn/planificacion/2019/Boletin%20Estadistico%20Diciembre.pdf

[GoI 2019] Government of India, Ministry of New and Renewable Energy, Programme/Scheme wise Physical Progress in 2019-209 & Cumulative up to July, 2019; https://mnre.gov.in/physical-progress-achievements

[GoJ 2012] Government of Jordan, Law No 13 of 2012, Renewable Energy and Energy Efficiency Law, 16 April 2012,
http://www.memr.gov.jo/EchoBusV3.0/SystemAssets/PDFs/EN/Laws/CleanVersionFinalRenewableEnergyEnergyEfficiencyLaw.pdf

[GoK 2010] Ministry of Energy, Kenya, Feed-in-tariffs policy for wind, biomass, small hydros, geothermal, biogas and solar, 1st revision, January 2010,
http://www.erc.go.ke/erc/fitpolicy.pdf

[GoK 2013] Government of Kazakhstan, Press Release, 5 February 2013

[GoM 2008] Decreto por el que se expide la Ley para el Aprovechamiento de Energías Renovables y el Financiamiento de la Transición Energética, *Diario Oficial* (Primera Sección) 88 (Mexico), 28 November 2008, http://www.diputados.gob.mx/LeyesBiblio/ref/laerfte/LAERFTE_orig_28nov08.pdf

[GoM 2012] Se Expide la Ley General de Chambio Climático, *Diario Oficial* (Segunda Sección) 1 (Mexico), 6 June 2012, http://www.diputados.gob.mx/LeyesBiblio/ref/lgcc/LGCC_orig_06jun12.pdf

[GoP 2006] Government of Pakistan, Policy for development of renewable energy for power generation, December 2006

[GoP 2016] Dziennik Ustaw Rzeczypospolitej Polskiej Warszawa, dnia 28 czerwca 2016 r. Poz. 925 USTAWA z dnia 22 czerwca 2016 r. o zmianie ustawy o odnawialnych źródłach energii oraz niektórych innych ustaw http://dziennikustaw.gov.pl/du/2016/925/1

[GoP 2019] Premier Mateusz Morawiecki podczas konferencji #MójPrąd, 23 July 2019 https://youtu.be/x5RH-80g6nY

[GoR 2016] Resolution of the Government of the Russian Federation, No. 850-r of 5 May 2016

[GoS 2008] Act No 34 of 2008: National Energy Act, *Government Gazette*, Republic of South Africa, Vol. 521, No 31638, 24 November 2008, http://www.info.gov.za/view/DownloadFileAction?id=92826

[GoS 2012] Government of Singapore, Energy Conservation Act 2012, Government Gazette, Acts Supplement, 2012 No 12, Friday 1 June 2012

[GoS 2017] Ministerio de Energía, Turismo y Agenda Digital, Nota de prensa, 27.07.2017, Listado de los adjudicatarios en la subasta de renovables de julio, http://www.minetad.gob.es/es-es/gabineteprensa/notasprensa/2017/documents/170727%20listado%20adjudicatarios%20subasta%20renovables.pdf

[GoU 2013] The Government of Uganda, Rural Electrification Strategy and Plan, Period 2013 – 2022, 3 July 2013 http://www.rea.or.ug/resources/strategy%20and%20plan%202013-2022.pdf

[GoZ 2017] The Government of Zambia, 7th National Development Plan (SNDP) (2017 - 2021)

[GUK 2016] Government of UK, https://www.gov.uk/feed-in-tariffs/overview

[GUK 2019] Government of UK, National Statistics, Solar photovoltaics deployment (accessed 9 August 2019), https://www.gov.uk/government/statistics/solar-photovoltaics-deployment

[Gwe 2019] Global Wind Energy Council, Global Wind Report 2018, April 2019

[Haa 2017] Haas, R., Resch, G., Burgholzer, B., Totschnig, G., Lettner, G., Geipel, J., Endbericht - Stromzukunft Österreich 2030 - Analyse der Erfordernisse und Konsequenzen eines ambitionierten Ausbaus erneuerbarer Energien, Technische Universität Wien, Mai 2017, https://www.eeg.tuwien.ac.at/eeg.tuwien.ac.at_pages/research/downloads/PR_464_final_report_Stromzukunft_Oesterreich_2030_(TU_Wien_-_EEG_Mai_2017-final).pdf

[Hed 2019] Issuance of power generation informative report for the non-interconnected islands, April 2019 http://www.deddie.gr

[Hep 2019] Hrvatska Elektroprivreda, Press Release, 08 April 2019 https://www.hep.hr/news/hep-to-invest-hrk-750-million-into-solar-power-plants-by-2023/3424

[Hir 2013] Hirth, L., 'The market value of variable renewables', *Energy Economics*, Vol. 38, 2013, pp. 218-236

[Hro 2019] HROTE, Data on RES and HE-CHP Feed-In Support System – May 2019, https://files.hrote.hr/files/PDFen/OIEIK/Monthly_Report_may_2019.pdf

[Hul 2015] Thomas Huld, Anna Amillo, Estimating pv module performance over large geographical regions: the role of irradiance, air temperature, wind speed and solar spectrum, Energies 2015;8:5159–81

[Hul 2018] Thomas Huld, EC JRC photovoltaic geographical information system. PVGIS); 2018

[IEA 2014] IEA, PVPS, Trends 2014 in photovoltaic applications, Report IEA-PVPS T1-25:2014

[IEA 2016] International Energy Agency, Medium-Term Renewable Energy Market Report 2016 - Market Trends and Projections to 2021, 278 pages, ISBN 978-92-64-26497-7

[IEA 2017] IEA, Energy Technology Perspectives, 2017, 441 p., ISBN: 978-92-64-27597-3

[IEA 2018] International Energy Agency, International Energy Agency, Renewable Energy Market Report 2018 - Market Trends and Projections to 2023, 210 pages, ISBN 978-92-64-30684-4

[IEA 2019] International Energy Agency, World Energy Investment 2019, May 2019, https://www.iea.org/wei2019/

[IEA 2019a] International Energy Agency, Tracking Clean Energy Progress, 2019, https://www.iea.org/tcep/

[IEA 2019b] International Energy Agency, Renewable Energy Market Report 2019 - Market Trends and Projections to 2024, 204 pages, ISBN 978-92-64-35173-8

[IEA 2019b] International Energy Agency, 2018 Snapshot of Global PV Markets, April 2019, ISBN 978-3-906042-83-1

[IEA 2019c] International Energy Agency, World Energy Outlook 2019, 13 November 2019

[Ieo 2019] Instytutu Energetyki Odnawialnej, Czerviec 2019, Rynek fotowoltaiki w Polsce 2019

[Ikk 2019] Ikki O., PV Activities in Japan, Vol. 25, 2019

[IMF 2019] International Monetary Fund, IMF Working Paper, Fiscal Affairs Department, Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates, Prepared by David Coady, Ian Parry, Nghia-Piotr Le, and Baoping Shang, May 2019, WP/19/89

[Ins 2019] Institute for Sustainable Energy Policies, The share of renewable energy in total power generation in Japan in 2018, 5 April 2019

[Ire 2015] IRENA, 'Renewable energy prospects: United Arab Emirates', *REmap 2030 analysis,* March 2015

[Ire 2016] IRENA/ADFE, 17 January 2016, http://adfd.irena.org/contentimages/Cape %20Verde %20summary.pdf

[Ire 2019] IRENA, Renewable Energy Auctions: Status and Trends Beyond Price, Preliminary Findings, June 2019, ISBN 978-92-9260-136-2

[Ire 2019a] IRENA, Global Energy Transformation: A roadmap to 2050, 2019 edition, April 2019, ISBN 978-92-9260-121-8

[Itr 2019] International Technology Roadmap for Photovoltaic (ITRPV), 2018 Results, 10th Edition, March 2019

[Jäg 2013] Jäger-Waldau, A., PV status report 2013, Publications Office of the European Union, 2013, ISBN 978-92-79-32718-6 (pdf)

[Jäg 2014] Jäger-Waldau, A., PV status report 2014, Publications Office of the European Union, 2014, ISBN 978-92-79-44621-4 (pdf)

[Jäg 2016] Jäger-Waldau, A., PV Status Report 2016, Publications Office of the European Union, 2016, ISBN 978-92-79-63054-5 (print)

[Jäg 2017] Jäger-Waldau, A., PV Status Report 2017, Publications Office of the European Union, 2017, ISBN 978-92-79-74072-5 (print)

[Jäg 2018] A. Jäger-Waldau, PV Status Report 2018, November 2018, European Commission, ISBN 978-92-79-97466-3 (print)

[Jäg 2019] A. Jäger-Waldau, Ioannis Kougis, Nigel Tailor, Christian Thiel, The role of photovoltaics to half the GHG emissions in the EU by 2030, submitted

[Jäg 2019a] Arnulf Jäger-Waldau, Giovanna Adinolfi, Alexandra Batlle, Martin Braun, Christof Bucher, Alice Detollenaere, Kenn H.B. Frederiksen, Giorgio Graditi, Ricardo Guerrero Lemus, Johan Lindahl, Gerd Heilscher, Markus Kraiczy, Gaëtan Masson, Barry Mather, Christoph Mayr, Diana Moneta, Daniel Mugnier, John Nikoletatos, Gregory Neubourg, Glenn Platt and Mike B. Roberts, Electricity produced from photovoltaic systems in apartment buildings and self-consumption - Comparison of the situation in various IEA PVPS countries, Proceedings of the IEEE PVSC-46, 16 – 21 June 2019, Chicago, IL, USA

[Jas 2019] T. Jasan, Malaysia: ASEAN's biggest solar employer, The Asean Post, 21 June 2019, https://theaseanpost.com/article/malaysia-aseans-biggest-solar-employer

[Jet 2016] Jet Contractors, Press Release, 23 May 2016, Partenariat tripartite Jet Contractors — Haeron Solar — SIE

[Jou 2011] Journal Officiel de la Republique du Senegal, N° 6581 du Samedi 9 Avril 2011, LOI n° 2010-21 du 20 décembre 2010

[Jou 2017] Journal Officiel de la Republique Algerienn N° 15 (Traduction Française), 5 March 2017

[JvG 2014] JvG Thoma, Press Release, 18 February 2014, http://www.jvg-thoma.de/en/start/news/!/page/2

[Kaz 2011] Kaz Silicon, Project file, http://www.kazsilicon.kz/en/node/16

[Kaz 2014] Kazatomprom, News: Astana Solar will discuss the construction of solar power stations, 12 September 2014, http://kazatomprom.kz/en/#!/article/3091

[KfW 2013] Kreditanstalt für Wiederaufbau, KfW-Programm Erneuerbare Energien 'Speicher', Programmnummer 275 (Version 1)

[KfW 2016] Kreditanstalt für Wiederaufbau, KfW-Programm Erneuerbare Energien 'Speicher', Programmnummer 275 (Version 2)

[Ley 2019] U. von der Leyen, A Union that strives for more – My agenda for Europe; Political Guidelines for the next European Commission 2019 – 2024, 16 July 2019, https://ec.europa.eu/commission/sites/beta-political/files/political-guidelines-next-commission_en.pdf

[Los 2019] Los Angeles Times, Los Angeles OKs a deal for record-cheap solar power and battery storage, 10 September 2019

[MEF 2016] Ministère de l'Economie et des Finances. Burkina Faso. Plan national de développement économique et social (PNDES) 2016-2020, Ouagadougou, Burkina Faso, 2016

[MEM 2009] Ministry of Energy and Mining, Jamaica, Jamaica's National Energy Strategy 2009 – 2030, October 2009

[MEM 2012] Ministry of Energy and Minerals Tanzania, Strategic plan 2011/12-2015/16, November 2012

[MEM 2013] Ministry of Energy and Minerals Tanzania, Scaling-up renewable energy programme, April 2013, http://www.mem.go.tz/Portals/0/EasyDNNNewsDocuments/1033/0039_08052013-SREP_Tanzania %20IP_Final_Draft.pdf

[MEM 2017] Ministry of Energy and Mineral Resources, Indonesia, Regulation No. 10 of 2017 on the Principles of Power Purchase Agreements; Regulation No. 12 of 2017 on the Utilisation of Renewable Resources for Electricity

[MEM 2017a] Ministeria de Energía y Minas, Normativa de Generación Distribuida Renovable para Autoconsumo ,La Gaceta No.240 del 18 de Diciembre del 2017

[MEM 2019] Ministeria de Energía y Minas, Dirección General de Energía, República de Guatemala, Matriz de Generación Eléctrica , 2012-2018, https://www.mem.gob.gt/wp-content/uploads/2019/01/Matriz-de-Generaci%C3%B3n-El%C3%A9ctrica-2012-2018.pdf

[Mes 2019] Middle East Solar Industry Association, Middle East solar outlook for 2019

[MET 2017] Ministerio de Energía, Turismo y Agenda Digital, Nota de prensa, 27.07.2017, Listado de los adjudicatarios en la subasta de renovables de julio http://www.minetad.gob.es/es-es/gabineteprensa/notasprensa/2017/documents/170727%20listado%20adjudicatarios%20subasta%20renovables.pdf

[METI 2013] Japanese Ministry of Trade and Industry, Agency for Natural Resources and Energy; Announcement regarding the present status of introduction of facilities generating renewable energy as of 31 May 2013, http://www.meti.go.jp/english/press/2013/0820_01.html

[METI 2018] Japanese Ministry of Trade and Industry, 5th Strategic energy plan, Cabinet Decision on the New Strategic Energy Plan, 3 July 2018

[MME 2018] Ministério de Minas e Energia, Brasil, Boletim Mensal de Monitoramento do Sistema Elétrico Brasileiro, Dezembro / 2018 http://www.mme.gov.br/documents/1138781/1435504/Boletim+de+Monitoramento+do+Sistema+El%C3%A9trico+-+Dezembro+-+2018.pdf/2cc7ebd8-040b-4d1a-b4e6-c0ad5e1fca58

[MME 2019] Ministério de Minas e Energia, Brasil, Boletim Mensal de Monitoramento do Sistema Elétrico Brasileiro, Julho / 2019 http://www.mme.gov.br/web/guest/secretarias/energia-eletrica/publicacoes/boletim-de-monitoramento-do-sistema-eletrico/boletins-2019

[MoE 2016] Ministry of Energy, Renewable Enery and Energy Efficiency of Iran, Decree from Cabinet Ministers No. H 52375 T/153440 - Revised Feed in Tariff Rates (February 2016) and Directive from the Minster of Energy with No. 95/14273/30/100 (May 2016)

[MoE 2019] Ministry of Economic Affairs Taiwan, 2019 Renewable Energy FIT Rates, 18 March 2019 https://www.moea.gov.tw/MNS/english/news/News.aspx?kind=6&menu_id=176&news_id=83360

[MOT 2019] Ministry of Trade, Industry and Energy (MOTIE), South Korea, Press Release 9 August 2019, 태양광, 금년 보급목표(1.63GW) 7월말로 조기달성; http://www.motie.go.kr/motie/ne/presse/press2/bbs/bbsView.do?bbs_seq_n=161970&bbs_cd_n=81&currentPage=1&search_key_n=&cate_n=&dept_v=&search_val_v=

[MOT 2019a] Ministry of Trade, Industry and Energy (MOTIE), South Korea, Press Release 19 July 2019,역대 세계최대 수상태양광 사업, 새만금에서 본격 추진 -

산업부 전기위원회, 새만금 지역 2.1GW 수상태양광 발전사업 허가 - ▸민간자본 약 4.6조원, 연인원 160만명 건설인력 투입, 약 100만가구에 전력공급 가능; http://www.motie.go.kr/motie/ne/presse/press2/bbs/bbsView.do?bbs_seq_n=161921&bbs_cd_n=81&currentPage=51&search_key_n=title_v&cate_n=&dept_v=&search_val_v=

[MSE 2019] Ministero dello Sviluppo Economico, La situazione energetica nazionale NEL 2018, Giunio 2019, https://www.mise.gov.it/images/stories/documenti/relazione_annuale_situazione_energetica_nazionale_dati_2018.pdf

[Mub 2016] Mubadala, Press Release, 27 June 2016, DEWA announces the selected bidder for the 800 MW third phase of the Mohammed bin Rashid Al Maktoum Solar Park

[Nat 2016] The National, UAE eyes new clean energy generation target by 2030, 20 January 2016

[Nat 2016a] The National, Marubeni-Jinko submit world-record low bid for 350 MW Sweihan solar project in Abu Dhabi, 20 September 2016

[NEA 2017] 国家能源局(National Energy Administration), 关于可再生能源发展"十三五"规划实施的指导意见, 19 July 2017, http://zfxxgk.nea.gov.cn/auto87/201707/t20170728_2835.htm

[NEA 2019] 國家能源局 (National Energy Administration), 2018年光伏发电统计信息 (Photovoltaic power generation statistics for 2018), 19 March 2019, http://www.nea.gov.cn/2019-03/19/c_137907428.htm

[NEA 2019a] 國家能源局 (National Energy Administration), 2019年上半年光伏发电建设运行情况 (Photovoltaic power generation construction and operation in the first half of 2019), 23 August 2019, http://www.nea.gov.cn/2019-08/23/c_138330885.htm

[NEA 2019b] 國家能源局 (National Energy Administration), 国家能源局综合司关于公布2019年光伏发电项目国家补贴竞价结果的通知, 10 July 2019, http://zfxxgk.nea.gov.cn/auto87/201907/t20190711_3682.htm

[Neo 2017] Neoen, Press Release, 2 May 2017 https://www.neoen.com/var/fichiers/1554824122-cp-inauguration-providencia-solaren.pdf

[Neo 2018] Neoen, Annual Financial Report for the Fiscal Year Ended on December 31, 2018, https://www.neoen.com/var/fichiers/neoen-rfa-fyr-2018-veng.pdf

[Nre 2016] New and Renewable Energy Authority (NREA), Benban 1.8 GW PV Solar Park, Egypt, Strategig Environmental & Social Assessment – Final report, February 2016, https://www.eib.org/attachments/registers/65771943.pdf

[One 2015] Office National de l'Electricité et de l'Eau Potable (ONEE), Branche Electricité, 18 February 2015, Programme solaire photovoltaïque de 400 MWc de l'Office national de l'électricité et de l'eau potable — Branche Electricité

[Osi 2016] Osinergmin, Press Release, 16 February 2016, Otorgan buena pro a 13 proyectos de energía renovable

[PMV 2016] Prime Minister of Viet Nam, Decision No 428/QĐ-TTG dated 18 March 2016, The approval of revisions to the national power development plan from 2011 to 2020 with visions extended to 2030

[Ppc 2017] Powering Past Coal Alliance, 12 December 2017, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/666736/Final_Declaration_PPCA_111217.pdf

[Qst 2017] Qatar Solar Technologies, Press Release, 24 March 2017

[Ram 2017] M. Ram, D. Bogdanov, A. Aghahosseini, A.S. Oyewo, A. Gulagi, M. Child, H-J. Fell, C. Breyer, "Global Energy System based on 100% Renewable Energy - Power Sector", (2017), Study by Lappeenranta University of Technology and Energy Watch Group, Lappeenranta, Berlin, November 2017

[Ram 2019] Ram M., Bogdanov D., Aghahosseini A., Gulagi A., Oyewo A.S., Child M., Caldera U., Sadovskaia K., Farfan J., Barbosa LSNS., Fasihi M., Khalili S., Dalheimer B., Gruber G., Traber T., De Caluwe F., Fell H.-J., Breyer C. Global Energy System based on 100% Renewable Energy – Power, Heat, Transport and Desalination Sectors. Study by Lappeenranta University of Technology and Energy Watch Group, Lappeenranta, Berlin, March 2019

[Rea 2016] REA, 31 March 2016, Construction of a 55 MW solar power plant in Garissa, http://www.rea.co.ke/index.php?option=com_content&view=category&layout=blog&id=89&Itemid=511

[Red 2019] RED Elélectrica de España, Las energías renovables en el Sistema eléctrico español 2018

[Ren 2019] Renewables 2019 – Global Status Report, REN21 Secretariat, ISBN 978-3-9818911-7-1

[Res 2016] Gustav Resch, André Ortner, Marijke Welisch,Sebastian Busch, Lukas Liebmann, Gerhard Totschnig ., Policy Dialogue on the assessment and convergence of RES Policy in EU Member States, Technical Report, DIA-CORE, 2016

[RoG 2011] Parliament of Ghana, Renewable energy bill, http://www.parliament.gh/assets/file/Bills/Renewable %20Energy %20Bill %202011.pdf

[RoI 2014] Regulation of the Government of the Republic of Indonesia, No 79/2014 concerning The National Energy Policy

[RoK 2009] Law of the Republic of Kazakhstan, from 4 July 2009 of No 165-IV ZRK, about support of usage of renewable energy sources, http://cis-legislation.com/document.fwx?rgn=28433

[RoN 2005] Ley No. 532, Ley Para la Promocíon de Generacíon Eléctrica con Fuentes Renovables, Aprobada el 13 de Abril del 2005, La Gaceta No.102 del 27 de Mayo del 2005

[RoP 2017] Republic of the Philippines, Department of Energy, Summary of Renewable Energy (RE) Projects as of December 31, 2017

[RoP 2019] Republic of the Philippines, Department of Energy, 2018 Power Statistics, https://www.doe.gov.ph/sites/default/files/pdf/energy_statistics/01_2018_power_statistics_as_of_29_march_2019_summary.pdf

[Rot 2018] République Tunisienne, Ministère de l’Industrie et des Petites et Moyennes Entreprises, Résultat du premier Round de l'appel à projet pour la production d’électricité à partir des énergies renouvelables dans le cadre du régime des autorisations, 03 Mai 2018, http://www.energymines.gov.tn/web/Actualites/resultat-aap.pdf

[RoT 2019] République Tunisienne, Ministère de l’Industrie et des Petites et Moyennes Entreprises, Résultat du deuxième round de l'appel à projet pour la production de l'électricité à partir de l'énergie éolienne assujettie au régime des autorisations Projets photovoltaïques avec capacité maximale de 10 MW, 19 Mars 2019, http://www.energymines.gov.tn/web/documents/resultat-second-round-solaire-10mw.pdf

[RoT 2019a] République Tunisienne, Ministère de l’Industrie et des Petites et Moyennes Entreprises, Résultat du deuxième round de l'appel à projet pour la production de l'électricité à partir de l'énergie éolienne assujettie au régime des autorisations Projets photovoltaïques avec capacité maximale de 1MW, 24 Avril 2019, http://www.energymines.gov.tn/web/documents/resultat-second-round-solaire-1mw.pdf

[RoT 2019b] République Tunisienne, Ministère de l'Industrie et des Petites et Moyennes Entreprises, APPEL A PROJETS pour la production d'électricité à partir des énergies renouvelables dans le cadre du régime des autorisations Troisième round, 11 Juillet 2019, http://www.energymines.gov.tn/web/autorisation-thirdround.htm

[RoU 2019] Embassy of the Republic of Uganda, Berlin – Germany, Press release 16 January 2019, https://berlin.mofa.go.ug/data-dnews-128-GERMANY-BASED-UGANDAN-INVESTS-US$24.5-MILLION-IN-PILOT-SOLAR-POWER-PARK.html

[Rte 2019] RTE Réseau de transport d'électricité, 2019, Panorama of Renewable Power in France in 2018, https://www.rte-france.com/sites/default/files/angpanoramat4-2018hd.pdf

[RVO 2019] Rijksdienst voor Ondernemend Nederland, Stimulering duurzame energie-productie (SDE+), (http://www.rvo.nl/)

[Sea 2014] Sustainable Energy Association of Singapore, A case for sustainability: Accelerating the case for Renewable Energy in Singapore, 20 January 2014

[Sed 2019] Sustainable Energy Development Authority, National Survey Report of PV Power Applications in Malaysia 2018, IEA PVPS 2019

[Sol 2014] Solar Tribune, PV equipment spending to rebound in 2015, 4 February 2014, https://solartribune.com/pv-equipment-spending-to-rebound-in-2015-2014-02-04/

[Sol 2019] Solar Power Europe, Global market outlook for solar power 2019-2023, July 2019, ISBN 978-90-82-71432-6

[Sol 2019a] Solar Choice, PV price index http://www.solarchoice.net.au

[SSS 2018] Scaling Solar Senegal, Latest Tender Results, 3 April 2018, http://www.finergreen.com/wp-content/uploads/2017/04/18-04-06-Senegal-Scaling-Solar-Tender-Results.pdf

[Sta 2019] Statistique Publique, Tableau de bord : solaire photovoltaïque, Quatrième trimestre 2018, 28/02/2019, https://www.statistiques.developpement-durable.gouv.fr/tableau-de-bord-solaire-photovoltaique-quatrieme-trimestre-2018

[Ste 2013] Société Tunisienne de l'Electricité et du Gaz, Prosol Elec, 2013.

[Sys 2019] Systèmes Solaires, le journal du photovoltaique, Photovoltaic energy barometer, April 2019, ISSN 0295-5873

[TCR 2019] Türkiye Cumhuriyeti Resmî Gazete, 10 Mayıs 2019, Sayı : 30770 http://www.resmigazete.gov.tr/eskiler/2019/05/20190510.pdf

[Tei 2019] Teiaş, Türkiye Elektrik Sistemi Kuruluş ve Kaynaklara Göre Kurulu Güç, https://www.teias.gov.tr/sites/default/files/2019-02/kurulu_guc_ocak_2019.pdf

[Ter 2019] TERNA, Rapporto mensile sul sistema elettrico, Consuntivo Giugno 2019

[Tes 2018] Tanzania Electric Supply Company Ltd., Tender No. PA/01/2018-19/HQ/N/032, for Qualification of Larger Solar Power Generation Projects

[Uec 2013] Ueckerdt, F., Hirth, L., Luderer, G. and Edenhofer, O., *System LCOE: What are the costs of variable renewables?* Social Science Research Network, SSRN-id2200572, 14 January 2013, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2200572

[UNFC 2016] United Nations Framework Convention on Climate Change, 5 October 2016, Paris Agreement — status of ratification, http://unfccc.int/paris_agreement/items/9444.php

[Vdm 2019] VDMA, Press Release European photovoltaic production can be profitable, 14 August 2019, https://pv.vdma.org/documents/105945/39287166/pr_vdma_study_pv_cost%20comparison_final_en_1565787427224.pdf/85b54816-7f5c-5a92-6c56-72d84f6edc48

[Ven 2013] Ventures Africa, Ethiopia Awards 300 MW solar contract to US firms, 25 November 2013, http://www.ventures-africa.com/2013/11/ethiopia-awards-300mw-solar-contract-to-us-firms/

[Wär 2017] Wärtsilä Corporation, Project reference: Essakane Solar SAS

[Wan 2015] Wan, J.S., The Health Impacts of Energy Choices, Healthy Energy Initiative http://www.healthyenergyinitiative.org/wp-content/uploads/2015/10/Health-Impacts-of-Energy-Choices_DigitalVersion.pdf

[Wan 2016] Wang, L., Economic Information Daily, 29 January 2016, '十三五"可再生能源五年新投2.3万亿

[Woo 2019] Wood Mackenzie and Solar Industry Association, U.S. solar market insight, Executive summary, 2018 Year in Review, March 2019

[Woo 2019a] Wood Mackenzie and Solar Industry Association, U.S. solar market insight, Executive summary, Q3 2019

[Wrb 2016] WRB Enterprises, Press release, 28 August 2016

List of abbreviations and definitions

AC	alternating current
ADB	Asian Development Bank
ASP	average selling price
BNEF	Bloomberg New Energy Finance
BOS	balance of system
bps	base points (100 base points are 1%)
CAGR	compound annual growth rate
CAPEX	capital expenditure
CEL	Clean Energy Certificates
COP	Conference of the Parties
CPV	concentrating photovoltaics
CTO	chief technology officer
CSP	concentrating solar thermal power
CWaPE	Wallonian Energy Commission
°C	degree Celsius
DC	direct current
DoE	Department of Energy
EEG	Energie Einspeisegesetz (energy feed in law)
ETP	Energy Technology Perspectives
EU	European Union
FiT	feed-in tariff
FY	financial year
GDP	gross domestic product
GSE	Gestore dei Servizi Energetici
GW	Giga Watt
H1	1st half year
IEA	International Energy Agency
IFC	International Finance Corporation
IMF	International Monetary Fund
IPP	independent power producers
IRENA	International Renewable Energy Agency
ITC	investment tax credit
JJNSM	Jawaharlal Nehru National Solar Mission
JRC	Joint Research Centre
KfW	Kreditanstalt für Wiederaufbau
kW	kilo Watt
LCOE	levelised cost of electricity

LIBOR	London Interbank Offered Rate
MASEN	Moroccan Agency for Solar Energy
MNRE	Ministry of New and Renewable Energy
METI	Ministry of Economy, Trade and Industry
MW	Mega Watt
NREAP	National Renewable Energy Action Plan
OEM	original equipment manufacturing
OPEX	operational expenditure
O&M	operation and maintenance
PPA	power purchase agreement
PV	photovoltaic
Q1	1st quarter
RES	renewable energy sources
ROC	renewable obligation certificate
ROI	return on investment
RPS	renewable portfolio standard
RTE	réseau de transport d'électricité
R & D	research and development
SDE+	Stimulering Duurzame Energieproductie
SHS	solar home system
SNEC	Shanghai New International Expo Centre
TSO	transmission system operator
TW	Terra Watt
VAT	value added tax
WACC	weighted cost of capital
WEO	World Energy Outlook
Wh	Watt hour
Wp	Watt peak
2DS	2 °C scenario
B2DS	1.75 °C scenario

List of figures

List of tables

KJ-NA-29938-EN-N

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

Joint Research Centre

EU Science Hub

Publications Office of the European Union

doi:10.2760/326629
ISBN: 978-92-76-12608-9