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PV Status Report 2014

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Abstract

Photovoltaics is a solar power technology to generate 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 solar systems, ranging from a few Watts of electricity output to multi Megawatt power stations. The unique format of the Photovoltaic Status Report combines international up-to-date information of Photovoltaics. These data are collected on a regular basis from public and commercial studies and crosschecked with personal communications. Regular fact-finding missions with company visits, as well as meetings with officials from funding organisations and policy makers, complete the picture. Growth in the solar Photovoltaic sector has been robust. The Compound Annual Growth Rate over the last decade was over 50%, 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 public interested, as well as decision-makers in policy and industry.

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PREFACE

In June 2009, the European Directive 2009/28/EC on the promotion of the use of energy from renewable sources came into force. Not only does it set mandatory targets for Member States for 2020, but it also gives a trajectory for how to reach them. The aim of the Directive is to provide the measures necessary for Europe to reduce its greenhouse gas emissions by 20 % by 2020, in order to support the worldwide stabilisation of atmospheric greenhouse gases in the 450 to 550 ppm range.

In 2014, the International Energy Agency (IEA) estimated in its 2014 Energy Technology Perspectives that additional investments needed to decarbonise the energy system in the low-carbon scenario (2 °C scenario, 2DS) by 2050 are in the order of USD_{2012} 44 trillion (EUR 32.6 trillion). At first sight, this looks like a lot of additional investment, but the report also states that these investments are more than offset by more than USD_{2012} 115 trillion (EUR 85.2 trillion) in fuel savings. In total, this leads to net savings of more than USD_{2012} 77 trillion (EUR 57 trillion) over the next 45 years.

Another remarkable statement is: *"The high renewable scenario (2DS hi-Ren) probes solar energy to supply the largest share of global electricity by 2040."* These findings are supported by the new IEA PV Roadmap as well as the IEA Medium-Term Renewable Energy Market Report 2014 which estimates that cumulative installed capacity of solar photovoltaic electricity systems will more than triple to over 440 GW by 2020 compared to 2013.

During the European Council meeting on 23-24 October 2014, the following Conclusions on 2030 Climate and Energy Policy Framework were adopted:

- The European Council endorsed a binding EU target of at least 40 % domestic reduction in greenhouse gas emissions by 2030 compared to 1990.
- An EU target of at least 27 % is set for the share of renewable energy consumed in the EU in 2030. This target will be binding at EU level.
- An indicative target at the EU level of at least 27 % is set for improving energy efficiency in 2030 compared to projections of future energy consumption.

Photovoltaics (PV) is a key technology option for implementing the shift to a decarbonised energy supply. Solar resources in Europe and across the world are abundant and cannot be monopolised by one country. Regardless of how fast oil prices and energy prices increase in the future, and the reasons behind these increases, photovoltaics and other renewable energies are the only ones offering the stabilisation of, or even a reduction in future prices.

From 2008 to the second quarter of 2014, residential PV electricity system prices fell by over 70 % in most competitive markets, and in an increasing number of markets the cost of PV-generated electricity is already cheaper than residential electricity retail prices. It is interesting to note that module prices decreased even more, by over 80%, during the same period and now represent less than 40 % of the costs of an installed PV system. Due to falling PV system prices and increasing electricity prices, the number of such markets is steadily increasing. Moreover, the nuclear accident which took place in Fukushima in March 2011 has brought about a shift in energy investments toward more renewables and PV systems. In 2013, solar energy attracted 53.3 % of all new renewable energy investments or USD 111.4 billion (EUR 82.5 billion). Despite the 19 % decrease in investments in small, distributed PV energy systems amounted to almost USD 60 billion (EUR 44.4 billion).

In 2013, PV industry production rose again although more modestly than in previous years, increasing by about 15 % and reaching a worldwide production volume of about 40 GW of photovoltaic modules. The compound annual growth rate (CAGR) over the last decade was about 50 %, which makes photovoltaics one of the fastest growing industries at present.

The 13th edition of the PV Status Report gives an overview of current trends. Over the last 15 years, 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. Any additional information would be most welcome and will be used to update the report.

Ispra, November 2014

Arnulf Jäger-Waldau
European Commission
Joint Research Centre, Renewables and Energy Efficiency Unit

TABLE OF CONTENTS

1. INTRODUCTION

Production data for global cell production[1] in 2013 varied between 35 GW (gigawatt) and 42 GW. The uncertainty in this data is due to the highly competitive market environment, as well as the fact that some companies report shipment figures, others report sales, and others report production figures. In addition, Original Equipment Manufacturing (OEM) increased significantly, thereby adding to the uncertainties in calculating production figures. In 2013, the main markets shifted away from Europe to Asia, mainly due to greater demand in China and Japan.

The data presented, which were collected from listed companies' stock-market reports, market reports and colleagues, were compared to various data sources and resulted in an estimate of 39.8 GW (Fig. 1), representing a moderate increase of about 14 % compared to 2012. For 2014, different consultancies expect a further increase between 10 % and 25 %.

Since 2000, total PV production has increased by almost two orders of magnitude, and over the last decade the CAGR has been about 55 %. The most rapid growth in annual production over the last five years has been observed in Asia, where China and Taiwan together now account for more than 70 % of worldwide production.

1 Solar cell production capacities 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 included,
- companies which purchase these circuits and make cells are not included.

2 Exchange rate: EUR 1.00 = USD 1.35

Publicly traded companies manufacturing products along the value chain, installing PV electricity systems, or offering related services have attracted a growing number of private and institutional investors. In 2013, worldwide new investments in clean energy fell again by 11 % compared to 2012 to USD 254 billion (EUR 188 billion[2]), which included USD 29 billion (EUR 21.5 billion) corporate and government research and development (R&D) spending [Blo 2014, Pew 2014].

In 2013, clean energy markets outside the Group of 20 (G20) continued to grow, adding about 15 % to exceed USD 27 billion (EUR 20 billion), whereas investments in the G20 countries fell again by 16 % to USD 187 billion (EUR 138.5 billion). Despite the overall decline in investments, the drop in renewable energy system prices, especially solar photovoltaics, almost compensated for this and allowed these investments to be used for installing 87 GW of new clean energy generation capacity, just 1 GW less than in 2012, bringing the total to 735 GW and thus capable of producing more than 1 700 TWh (terawatt hours) of electricity or 70 % of the electricity generated by nuclear power plants worldwide.

For the fourth year in a row, solar power attracted the largest number of new investments in renewable energies. Despite a 23 % decline in solar energy investments, it attracted 52 % of all new renewable energy investments or USD 97.6 billion (EUR 72.3 billion) [Pew 2014]. It is worth mentioning that despite this 23 % decline in solar energy investments, the annual installed photovoltaic solar energy capacity also increased by about 23 % to 39.5 GW.

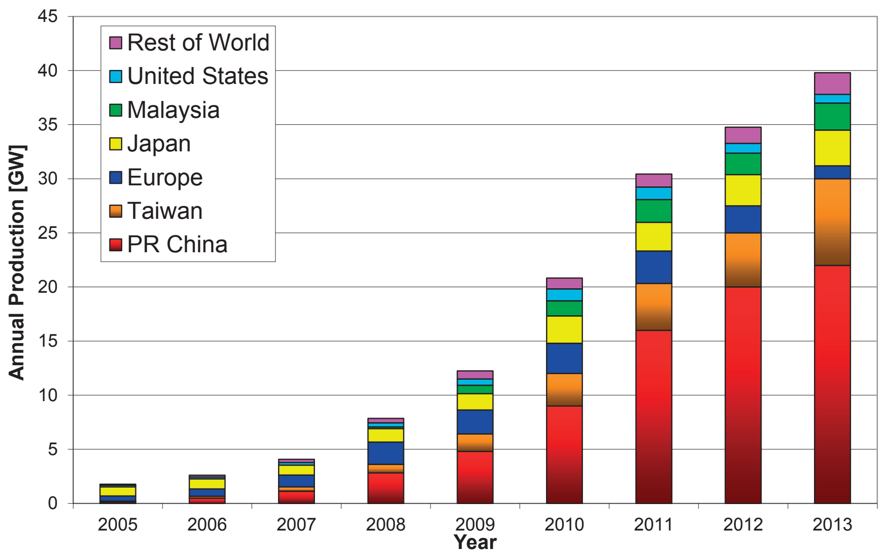

Fig. 1: World PV cell/module production from 2005 to 2013 (data source: Photon International [Pho 2012], PV Activities in Japan [Pva 2014], PV News [Pvn 2014] and own analysis)

In contrast to Europe and the Americas, where new investments in renewable energy fell by 42 % and 8 % respectively, new investments continued to rise in Asia/Oceania [Pew 2014]. The leading country in new renewable energy investment was China at USD 54.2 billion (EUR 40.2 billion), followed by the USA at USD 36.7 billion (EUR 27.2 billion) and Japan at USD 28.6 billion (EUR 21.2 billion).

The European Union (EU) as a whole saw investments of USD 34 billion (EUR 25.2 billion), mainly in the United Kingdom (EUR 9.2 billion) – the only European market with increased investments – and Germany (EUR 7.5 billion). Japan recorded the largest change in 2013, with an 80 % increase compared to 2012. Looking at five-year growth, South Africa is leading with 96 % followed by Japan (57 %) and Australia (32 %), whereas the EU saw a decline of 6 %.

Overcapacity in the solar industry has led to continuous price pressure along the value chain and resulted in a reduction in spot market prices for polysilicon materials, solar wafers and cells, as well as solar modules. Since 2008, PV module prices have fallen by 80 % and, in 2012 alone, by 20 % [Blo 2013]. These rapid price decreases have put all solar companies under enormous pressure and access to fresh capital was and remains key to survival. It is believed that this situation will continue to improve slowly, but will persist until 2015 when the global PV market should exceed 50 GW of new installations. The slight, but continuous rise in polysilicon spot prices since the beginning of 2013 and the levelling of module prices indicate that older production capacity has been temporarily or permanently shut down and actual production and demand are growing closer. Overall, prices might stabilise for a while until they are back on the learning curve. PV system hardware costs are more or less the same worldwide, but the so-called 'soft costs', which mainly comprise financing and permit costs, as well as labour requirements and installer/system integrator profits, are the main reason for the significant differences which are still observed. As markets develop and mature, worldwide system prices are converging.

The still difficult financial situation worldwide and the fact that regulatory schemes continue to change in the short term, which reduces long-term investor confidence, mean that risk premiums are added and project financing is made more difficult. On the other hand, the falling system prices have already opened up new markets, offering the prospect of further growth in the industry – at least for those companies with the ability to expand and reduce their costs at the same rate.

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. In August 2014, the IEA published its third Medium-Term Renewable Energy Market Report, and raised the predicted increased capacity to over 440 GW of cumulative PV installations in 2020 [IEA 2014].

Market predictions for the 2014 PV market vary from 40 GW according to the conservative forecast of SPV Market Research, 45 GW in Bloomberg's conservative prediction and 49.6 GW in its optimistic scenario [Blo 2014, Spv 2014]. In 2015, analysts expect a further increase to > 50 GW, driven by the continuous growth of the Asian markets. Overcapacities still exist in cell and module manufacturing, but the gap between demand and possible supply is shrinking. The ongoing technology development and heightened cell and module efficiencies require an upgrade of older facilities in order to stay competitive.

The current solar cell technologies are well established and provide a reliable product, with sufficient efficiency and guaranteed energy output for at least 25 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.

Over 85 % of current production uses wafer-based crystalline silicon technology. Projected silicon production capacities for 2014 vary between 306 000 tonnes [Blo 2014a] and 426 360 tonnes [Ikk 2014]. It is estimated that about 27 000 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 current global average is about 5.4 g/Wp.

As in other technology areas, new products will enter the market, enabling further cost reductions. Concentrating Photovoltaics (CPV) is an emerging market. There are two main types: either high concentration > 300 suns (HCPV) or low to medium concentration with a concentration factor of 2 to approximately 300. In order to maximise the benefits of CPV, the technology requires high direct normal irradiation (DNI) which occurs in a limited geographical range – the Earth's 'sun belt'. In addition, dye cells are being made ready for the market. The development of these technologies is being accelerated by the positive development of the PV market as a whole, but the competition for the right business case is becoming increasingly fierce.

Thus, it can be concluded that in order to maintain the extremely high growth rate of the PV industry, different technology pathways must be pursued simultaneously. The cost share of solar modules in a PV system has dropped below 40 % in residential systems and below 50 % in commercial systems. In addition, even for a moderate financing cost of

5 %, the share of the investment costs in the levelised cost of electricity is only in the range of 40 %, whereas O&M (operations and maintenance) costs, permits and administration, fees and levies as well as financing costs make up the rest. These variable and soft costs must be targeted for further significant cost reductions.

With increasing shares of PV electricity in the grid, the economics of integration is of growing importance and urgent attention needs to be 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 cost of electricity generated by a PV module has dropped to below EUR 0.04/kWh, although the main cost component relates to getting the electricity from the module to where it is needed. Therefore, new innovative and cost-effective electricity system solutions overall for the integration of PV electricity are needed to establish photovoltaic electricity as an integral part of sustainable energy solutions. The optimisation of solar photovoltaic electricity plant operation has direct effect on the O&M costs, which play an increasing role for the economics of the PV installation. In addition to a further reduction of the non technical costs, further public support, especially for regulatory measures is needed.

2. THE PHOTOVOLTAIC MARKET

After the worldwide PV market more than doubled in 2010, the market grew again by almost 30 % in 2011 and a further 11 % in 2012, despite the difficult economic conditions. The 2010 market volume of 20.9 GW includes those systems in Italy which were reported under the second *conto energia* and installed but only connected in 2011. The stronger than expected market in China and Japan as well as the significant increase in installations in Asia, South Africa and the USA resulted in a new installed capacity of about 39.8 GW in 2013; and in 2014 an increase to about 47 GW is expected (Fig. 2). This mainly represents the grid-connected PV market. To what extent the off-grid and consumer product markets are included is not clear, but it is believed that a substantial part of these markets are not accounted for as it is very difficult to track them.

At the end of 2013, of the total global 140 GW of solar PV electricity generation capacity, the EU had a cumulative installed capacity of 80.7 GW, and was still leading in terms of total capacity of PV installations.

2.1 Asia and the Pacific region

Asia and the Pacific region continued its upward trend in annual installations of PV electricity system. The reasons for this development range from falling system prices, heightened awareness, favourable policies and the sustained use of solar power for rural electrification projects. Countries such as Australia, China, India, Indonesia, Japan, Malaysia, the Philippines, South Korea, Taiwan, Thailand and Vietnam continue a very positive upward trend, thanks to governmental commitment to the promotion of solar energy and the creation of sustainable cities.

In 2013, more than 23 GW of new PV electricity generation systems were installed in the region, which corresponds to a 270 % growth compared to 2012. The largest market was China with 12 GW, followed by Japan with more than 7 GW and India with over 1 GW. In 2014, a market increase to over 25 GW is expected, while in 2015, more than 30 GW could be installed.

2.1.1 Australia

In 2013, more than 800 MW of new solar PV electricity systems were installed in Australia, bringing the cumulative installed capacity of grid-connected PV systems to over 3.2 GW. As in 2011 and 2012, the market in 2013 was dominated by grid-connected residential systems. In the meantime, more than 1.2 million homes have been equipped with PV systems bringing the national penetration to an average of 15 %, and in some areas it even exceeds 30 %. The average PV system price paid by the customer for a grid-connected system fell from AUD 6/Wp (EUR 4.29/Wp[3]) in 2010 to AUD 3.9 /Wp (EUR 2.89/Wp[4]) in 2011, AUD 3.0/Wp (EUR 2.4/Wp[4]) in 2012, AUD 2.5/Wp (EUR 1.85/Wp[5]) in 2013, and below AUSD 2.0/Wp (EUR 1.38/Wp[6]) in the middle of 2014. As a result, the cost of PV-generated electricity has fallen to, or is even below, the average residential electricity rate of AUD 0.28/kWh (EUR 0.19/kWh).

3 Average exchange rate for 2010: EUR 1 = AUD 1.40
4 Average exchange rate for 2011 and 2013: EUR 1 = AUD 1.35
5 Average exchange rate for 2012: EUR 1 = AUD 1.25
6 Average exchange rate for 2014: EUR 1 = AUD 1.45

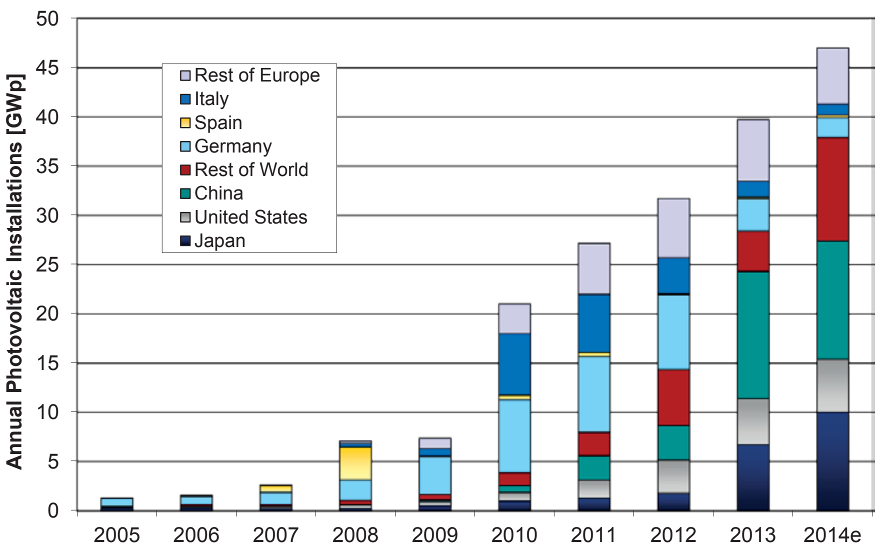

Fig. 2:
Annual PV installations from 2005 to 2014 (data source: [Epi 2014, Eur 2014] and own analysis)

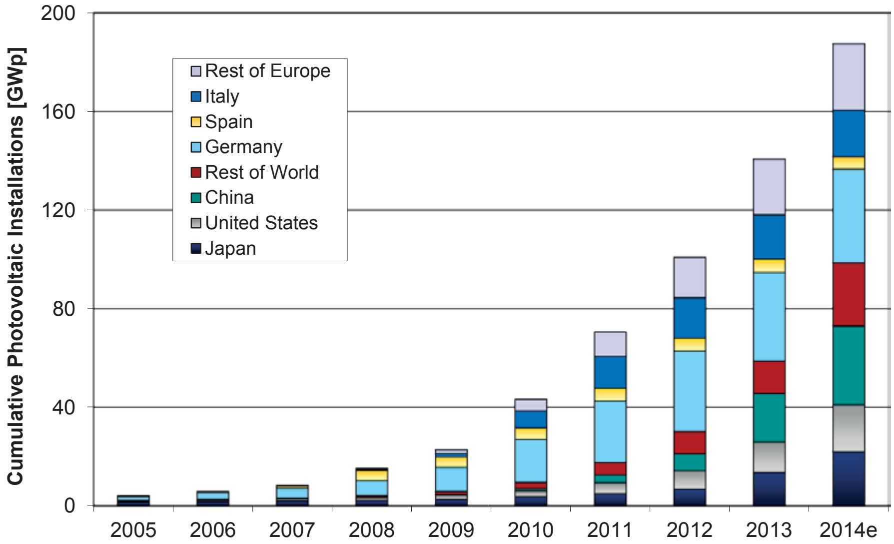

Fig. 3: Cumulative PV installations from 2005 to 2014 (data source: [Epi 2014, Eur 2014] and own analysis)

In 2013, PV electricity systems generated 3.82 TWh or about 1.6 % of Australia's total electricity. The total renewable electricity share was 14.76 % and this should increase to 20 % by 2020. For 2014, the market forecast is about 700 MW.

2.1.2 India

For 2013, market estimates for solar PV systems vary between 1.1 and 1.3 GW, due to the fact that some statistics cite the financial year (FY) and others the calendar year. According to the country's Ministry of New and Renewable Energy (MNRE), at the end of July 2014 the total capacity was 2.75 GW grid-connected and 175 MW off-grid PV capacity [GoI 2014]. The Indian Jawaharlal Nehru National Solar Mission (JJNSM) was launched in January 2010, in the hope that it would give impetus to the grid-connected market. The JJNSM aims to make India a global leader in solar energy and envisages an installed solar generation capacity of 20 GW by 2020, 100 GW by 2030, and 200 GW by 2050. Following the installation of just a few MW in 2010, in 2011 and 2012 installations began to pick up slowly, although the majority of the JJNSM projects will come on line from 2015 onwards. Market expectations for 2014 vary between 0.70 and 1.1 GW [Bri 2014, Icr 2014].

2.1.3 Israel

A feed-in tariff (FiT) was introduced in Israel in 2008 and four 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 there are plans to install about 1 GW of solar PV systems by the end of 2014. By August 2012, about 215 MW had been built and a further 300 MW approved [Blo 2012]. In 2013, around 244 MW were installed bringing the total capacity to about 480 MW. Market expectations for 2014 range from 250 to 350 MW.

2.1.4 Japan

In 2013, the Japanese market experienced significant growth, increasing its domestic shipments threefold to 7.5 GW. Cumulative installed capacity increased by about 7 GW to reach 13.6 GW at the end of 2013 [IEA 2014a]. Under a new FiT scheme, introduced in July 2012 [METI 2013], more than 68.4 GW had received approval as of the end of April 2014. Of these, projects with a total capacity of 9.5 GW have been commissioned and are in operation. Due to this huge discrepancy between actual installations and permits given, in October 2013 the Ministry of Economy, Trade and Industry (METI) started to revise the list of projects according to their actual status. Then it began to revoke permits for projects that had failed to secure land and equipment by the end of March 2014. For projects under the 2012 FiT regime with approximately 1.8 GW capacity FiT approval has already been cancelled and another 2.7 GW are under consideration. Despite this, market predictions are in the 10 to 12 GW range for 2014.

Until 2010, residential rooftop PV systems represented about 95 % of the Japanese market. In 2011, due to changes in the permit system, large ground-mounted systems as well as large commercial and industrial rooftop systems increased their market share to about 20 %. Of the 68.5 GW approved by the end of April 2014, only 2.8 GW or 4.3 % comprised systems smaller than 10 kWp. However, almost 79 % of these systems were actually connected to the grid. PV systems with capacities over 1 MW represented more than 55 % of the approved capacity, but only 6.5 % of them had started operation.

For new projects approved after 1 April 2014, the following tariffs apply: for commercial installations (total generated power) larger than 10 kWp, the tariff is now JPY 32/kWh (EUR[7] 0.232/kWh) for 20 years and for residential installations (surplus

[7] Exchange rate: EUR 1 = JPY 138

power) smaller than 10 kWp it is JPY 37/kWh (EUR 0.268/kWh) for 10 years [METI 2014].

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 was set for PV power in 2020. In July 2012, a METI panel proposed the long-awaited plan to reform the country's power market, and Japan's 4th Strategic Energy Plan was published in April 2014 [METI 2014a]. However, this plan is very vague about the role of renewables in the electricity sector, and only mentions the 20 % share suggested for 2030 by the Advisory Committee for Natural Resources and Energy back in 2010.

2.1.5 Malaysia

The Malaysia Building Integrated Photovoltaic (BIPV) 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. By 2015, about 1 GW must come from renewable energy sources, according to the Ministry of Energy, Green Technology and Water (KeTTA).

In April 2011, renewable energy FiTs were passed by the Malaysian Parliament with the target of 1.25 GW being installed by 2020. For the period from December 2011 to June 2014, PV had been allocated a total quota of 125 MW. The 2013 tariffs set by the Sustainable Energy Development Authority (SEDA) were between MRY 0.782 and 1.555/kWh (EUR 0.195 to 0.389/kWh[8]), depending on the type and system size. In addition, there is a small bonus for local module or inverter use, and an annual tariff digression is foreseen. According to SEDA, more than 149 MW of PV capacity had received FiT by the end of September 2014, while another 77.7 MW had already been approved [Sed 2014].

First Solar (USA), Hanwha Q CELLS (Korea/Germany), SunPower (USA) and more recently Panasonic (Japan) have all set up manufacturing plants in Malaysia, amounting to more than 3.8 GW of production capacities.

2.1.6 People's Republic of China

In 2013, the Chinese PV market of 12.9 GW was the largest worldwide, exceeding the 10 GW target for new PV installations for 2013 announced by the National Energy Administration (NEA) on 7 January 2013 [NEA 2013]. The total cumulative installed capacity increased to about 19.7 GW [IEA 2014a]. For 2014, a new capacity between 12 to 14 GW is expected in line with the NEA's announcement in January 2014 [NEA 2014].

The 2014 International Energy Agency (IEA) Renewable Energy Medium-Term Market Outlook expects an increase of total cumulative installed capacity to over 110 GW in 2020 [IEA 2014]. This is in line with the 70 GW target for 2017, announced by a joint statement of the National Development and Reform Commission (NDRC), the Ministry of Environmental Protection (MEP) and NEA in May 2014 [NEA 2014a].

According to the 12th Five Year Plan, which was adopted on 14 March 2011, China intends to cut its carbon footprint and become more energy efficient. The targets are 17 % fewer carbon dioxide emissions and 16 % less energy consumption per unit of gross domestic product (GDP). Under this Plan, total investment in the power sector is expected to reach USD 803 billion (EUR 618 billion), with USD 416 billion (EUR 320 billion) or 52 % being allocated to power generation and USD 386 billion (EUR 298 billion) for the construction of new transmission lines and other improvements to China's electrical grid.

On 24 February 2012, the Chinese Ministry of Industry and Information Technology (MIIT published its industrial restructuring and upgrading plan (2011-2015) for the PV industry [MII 2012]. In this document, the Ministry states that by 2015 it expects to be supporting only 'backbone' enterprises, which should produce a minimum of 50 000 tonnes of polysilicon, or 5 GW of solar cell or module production. The plan also projects a reduction in the cost of the electricity generated by PV systems to CNY 0.8/kWh (EUR 0.098/kWh[9]) by 2015 and CNY 0.06/kWh (EUR 0.074/kWh) by 2020.

In August 2012, the NEA released the new five-year plan for renewable energy for 2011-2015 [NEA 2012]. The plan estimated that between 2011 and 2015 new investments in renewable energy will total CNY 1.8 trillion (EUR 222 billion). China aims to add a total of 160 GW of new renewable energy capacity during the period 2011-2015, namely 61 GW hydro, 70 GW wind, 21 GW solar[10] (10 GW small distributed PV, 10 GW utility-scale PV and 1 GW solar thermal power), and 7.5 GW biomass. For 2020, the targets are set at 200 GW for wind, 50 GW for solar (27 GW small distributed PV, 20 GW utility-scale PV and 3 GW solar thermal power) and 30 GW for biomass.

The necessary investment figures are in line with a World Bank report stating that China needs an additional annual investment of USD 64 billion

[8] Exchange rate: EUR 1.0 = MRY 4.0
[9] Exchange rate for 2012: EUR 1.0 = CNY 8.1
[10] Already updated

(EUR 49.2 billion) over the next two decades to implement an 'energy-smart' growth strategy [WoB 2010]. However, the report also says that reductions in fuel costs through energy savings could largely pay for the additional investment costs. Based on a discount rate of 10 %, the annual net present value (NPV) of fuel cost savings from 2010 to 2030 would amount to USD 145 billion (EUR 111.5 billion), which is about USD 70 billion (EUR 53.8 billion) more than the annual NPV of the additional investment costs required.

2.1.7 South Korea

In 2013, about 450 MW of new PV systems were installed in South Korea, bringing the cumulative capacity to a total of almost 1.5 GW [IEA 2014a]. Since January 2012, Korea's Renewable Portfolio Standard (RPS) has officially replaced the FiTs. 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 5000 MW generation capacity to supply 3 % of their electricity from NRE by 2014, gradually increasing 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 has its own RPS set-aside quota of 1.2 GW for the period between 2012 and 2014 (originally 2015). About 410 MW were installed under this programme in 2013, while for 2014, about 550 to 600 MW could be allocated under it.

Under the RPS, income for power generated by renewable energy sources 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 systems.

2.1.8 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 is to increase Taiwan's renewable energy generation capacity by 6.5 GW to a total of 10 GW within 20 years. All types of renewable energy are being promoted: a total installation capacity of 9952 MW (accounting for 14.8 % of total power generation installation capacity) has been planned to take effect by 2025, including a new installation capacity of 6600 MW, so that the goal set by the Renewable Energy Development Act can be achieved five years earlier. By 2030, the total installation capacity will be further expanded to 12 502 MW (accounting for 16.1 % of total power generation installation capacity) and capable of generating 35.6 billion kWh of electricity, which is equivalent to the annual electricity consumption of 8.9 million households (accounting for 78 % of the nationwide electricity consumption by households). Targets for installed PV capacity are 750 MW by 2015 and 3.1 GW by 2030.

Between 2009 and 2012, a total capacity of 194 MW was installed, so that by the end of 2012 the total capacity was 222 MW [MoE 2013]. In 2013, about 170 MW of new PV systems were installed [IEA 2014a]. For 2014, around 210 MW of new installations are expected [Lan 2014].

In the second half of 2014, the FiTs for rooftop systems were TWD 7.17/kWh (EUR 0.184 /kWh[11]) for systems up to 10 kW, TWD 6.43/kWh (EUR 0.165/kWh) for systems between 10 and 100 kW, TWD 6.05/kWh (EUR 0.155/kWh) for systems between 100 and 500 kW, and TWD 5.22/kWh (EUR 0.134/kWh) for systems larger than 500 kW. Ground-mounted systems were allocated a tariff of TWD 4.93/kWh (EUR 0.126/kWh).

2.1.9 Thailand

Thailand enacted a 15-year Renewable Energy Development Plan (REDP) in early 2009, with a target to increase the renewable energy share to 20 % of the country's final energy consumption in 2022. Besides a range of tax incentives, solar PV electricity systems are eligible for a feed-in premium or 'Adder' for a period of 10 years. The original THB[12] 8 /kWh (EUR 0.190/kWh) Adder (facilities in the three southern provinces and those replacing diesel systems are eligible for an additional THB 1.5/kWh (EUR 0.036/kWh)) was reduced to THB 6.5/kWh (EUR 0.155/kWh) for those projects not approved before 28 June 2010. 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 are now being developed with power purchase agreements (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 10kW and 100 MW for systems between 10kW and 1 MW) as well as community-owned ground-mounted solar plants, in addition to the Adder scheme. The feed-in tariffs were set at THB 6.96/kWh (EUR 0.166/kWh) for residential size systems, THB 6.55/kWh (EUR 0.156 /kWh) for medium-sized building systems

[11] Exchange rate: EUR 1 = TWD 39
[12] Exchange rate: EUR 1 = THB 42

and industrial plants (< 250 kW) and 6.16 THB/kWh (0.147 EUR/kWh) for large building and industrial plants.

At the end of 2013, grid-connected PV had a capacity of about 825 MW, of which 440 MW were installed in that year [IEA 2014a].

2.1.10 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 (GEF), the German Kreditanstalt für Wiederaufbau (KfW), the German Technical Cooperation (GTZ), the Asian Development Bank (ADB) and the Islamic Development Bank. By June 2014, more than 3 million SHSs (50 - 60 W) had been installed in Bangladesh [WoB 2014]. Current installations rates are more than 70 000 units per month.
  On 30 June, the Government of Bangladesh signed a USD 78.4 million (EUR 60.3 million) credit agreement with the International Development Association (IDA), the World Bank Group's soft-loan arm. The money will go towards financing the Bangladesh Rural Electrification and Renewable Energy Development II (RERED II) project and will enable the installation of 480 000 additional SHS.

- **Indonesia:** The development of renewable energy is regulated in the context of the national energy policy by Presidential Regulation No. 5/2006 [RoI 2006]. The decree states that, in 2025, 11 % of the national primary energy mix should come from renewable energy sources with a target for solar PV set at 1000 MW. At the end of 2013, about 60 MW of solar PV systems had been installed, mainly for rural electrification purposes. The Indonesian Ministry of Energy and Mineral Resources has drafted a roadmap which foresees the installation of 220 MW between 2012 and 2015 [MEM 2012]. Indonesia published a tender for 150 MW of PV projects in 2013, but so far only about 12 MW have been awarded.

- **Kazakhstan:** The development of renewable energy is 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 renewable energy sources 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 May 2013, Zhambilskie Electricheskie Seti LLP signed a memorandum of understanding with NanoWin Thin Film Tech to build a 60 MW copper indium gallium selenide (CIGS) factory and a 5 MW solar plant [Nan 2013].
  In January 2014, a 2 MW ground-mounted solar power plant was completed in the city of Kapchagay in the Almaty Province [Bis 2014]. In mid-2014, the total PV capacity was estimated at about 3 MW.

- **Myanmar:** The country has a rural electrification rate of less than 29 %, with vast regions beyond the reach of the main grid. In the World Energy Outlook (WEO) 2012, the IEA states that Myanmar had the poorest level of energy access in all of Asia Pacific [IEA 2012]. In February 2014, the government published its Draft Electricity Law which includes the possibility of setting up small power producers (SPPs) 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 solar home systems with 80 to 200 W [ADB 2014]. At the end of August 2014, Bloomberg reported on an agreement between AOC Investment and the Myanmar Ministry of Electric Power to build two 150 MW PV power plants in the Myingyan and Meiktila districts by 2016 [Blo 2014b].

- **The Philippines**: The Renewable Energy Law was passed in December 2008 [RoP 2008]. Under the law, the Philippines must double the energy derived from renewable energy sources 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. The 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 installa-

tions to be implemented in the country over the next three years. It was suggested that a FiT of PHP 17.95/kWh (EUR 0.299/kWh[13]) 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 is 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 0.183/kWh[14]) and confirmed the digression rate.
At the end of 2012, about 2 MW of the 20 MW of installed PV systems were grid-connected. The Department of Energy reported that, by the end of August 2014, more than 1.3 GW of PV projects had been approved under the Renewable Energy Law and another 56 MW were pending [RoP 2014]. However, only 22 MW of this capacity was already operational.

- **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]. It is expected that the cumulative installed capacity will double in 2014 and exceed 28 MW by the end of this year.

- **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. At the end of 2011, about 5 MW of PV systems had been installed, mainly in off-grid applications.
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. According to the company, it has a production capacity of 200 MW in the first phase. The company is a subsidiary holding company of Powerway Group (PRC).

2.2 Europe and Turkey

Market conditions for photovoltaics differ substantially from country to country. This is due to different energy policies and public support programmes for renewable energies, especially photovoltaics, as well as the varying grades of liberalisation of domestic electricity markets.

A total of about 34.8 GW of new power capacity were installed in the EU last year and 21.8 GW were decommissioned, resulting in 13.0 GW of new net capacity (Fig. 4) [Epi 2014, Eur 2014, Ewe 2014, own analysis]. Renewable energy sources accounted for 24.9 GW or 71.5 % of all new power generation capacity. PV electricity generation capacity accounted for 10.6 GW, or 30.6 % of the new installed capacity.

In terms of new net capacity, wind power was first with 10.8 GW, followed by solar photovoltaics 10.6 GW, hydro 1.2 GW, biomass 0.7 GW, solar thermal power plants 0.4 GW, nuclear 120 MW and other sources 111 MW. The net installation capacity for coal-fired, gas-fired and oil-fired power plants was negative, with a decrease of 5.8 GW, 2.7 GW and 2.6 GW, respectively. It should be mentioned that in addition to the 15.5 GW of decommissioned gas-fired power plants another 5 GW were mothballed during 2012/13 [Cal 2014].

The net growth of renewable energy power generation capacity between 2000 and 2013 was 203 GW, compared to 103 GW for gas-fired capacity and a reduction in fuel-oil (-24 GW), coal (-19 GW) and

[13] Exchange rate for 2011: EUR 1 = PHP 60
[14] Exchange rate for 2012: EUR 1 = PHP 53

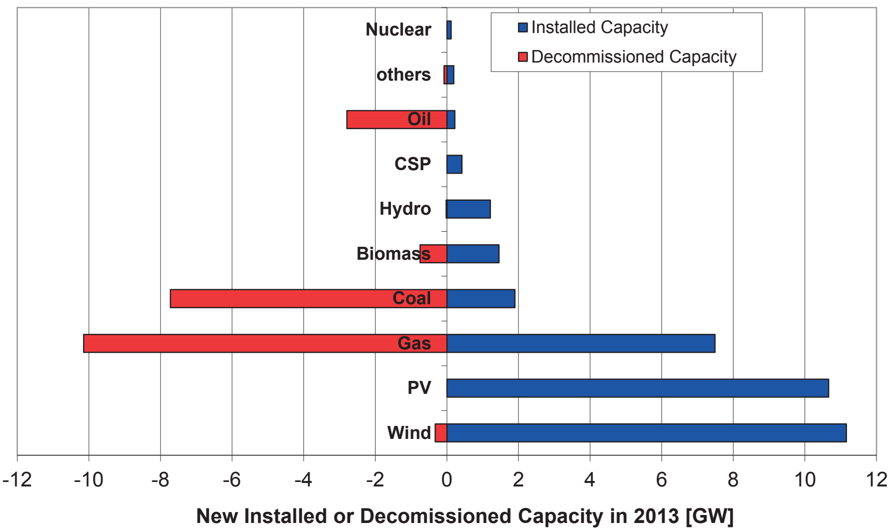

Fig. 4: New connected or decommissioned electricity generation capacity in the EU in 2013 (data source: [Epi 2014], [Eur 2014], [Ewe 2014] and own analysis)

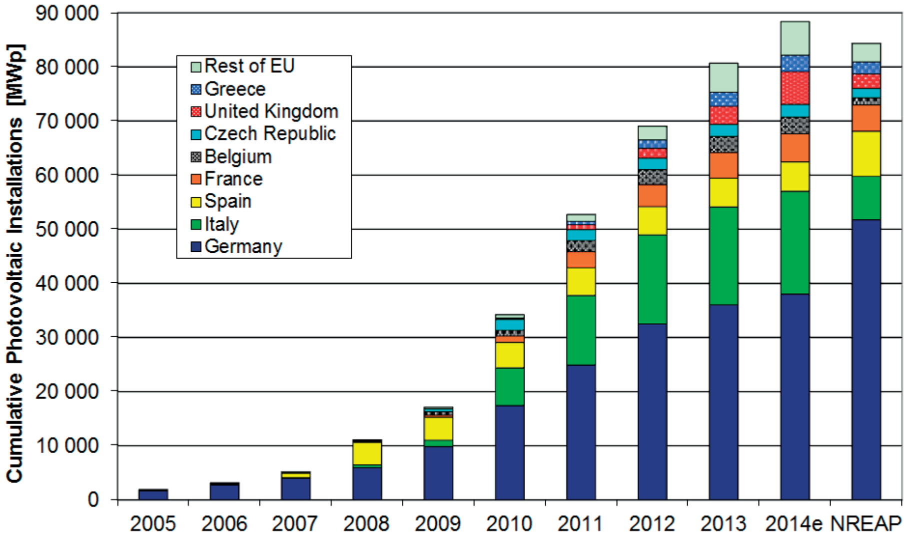

Fig. 5:
Cumulative installed grid-connected PV capacity in EU + Candidate Countries compared with the NREAP target for 2020
(data source: [Epi 2014], [Eur 2014] and own analysis)

nuclear (-14.9 GW). Together, wind (117.3 GW) and PV (80.7 GW) together now represent about 55 % of the total renewable power capacity of 357 GW. This increased the total share of renewable power capacity from 22.5 % in 2000 to 40.2 % in 2013.

Since 2005, solar PV electricity generation capacity has increased from 1.9 GW in 2005 to 80.7 GW at the end of 2013 (Fig. 5). Already in 2014, the 2020 National Renewable Energy Action Plan (NREAP) target of 84.4 GW will be exceeded, reaching about 88.4 GW.

With a cumulative installed capacity of 80.7 GW, the EU is still leading in PV installations with 57 % of the global total of 140 GW of solar photovoltaic electricity generation capacity at the end of 2013, although this was down from 70 % recorded at the end of 2012.

At first glance, this development appears to be a success. However, by looking at the annual installations it becomes obvious that Europe's share is not only declining in relation to a growing market worldwide, but also in actual installation figures (Fig. 6). According to the IEA Medium-Term Renewable Energy Market Report 2014, this share will drop below 30 % by 2020 due to a stagnant market of 7 to 8 GW between 2014 and 2020 [IEA 2014].

What are the reasons and main consequences of this development?

Some Member States had introduced support schemes which were not designed to react fast enough to the very rapidly growing market and this led to unsustainable local market growth rates. To counteract this, unpredictable and frequent changes in the support schemes, as well as legal requirements, led to installation peaks before the announced deadlines and high uncertainty for potential investors. A number of retroactive changes have further decreased investment confidence.

One of the consequences is the effect on local jobs and the local economy: The growth of the PV industry in Europe resulted in the generation of over 260 000 jobs or 38 % of global employment in the PV sector in 2011 [Jäg 2014]. Over 75 % of these 260 000 jobs were in operating and installing solar photovoltaic electricity systems. Almost all of them were local European jobs contributing to the European GDP. The

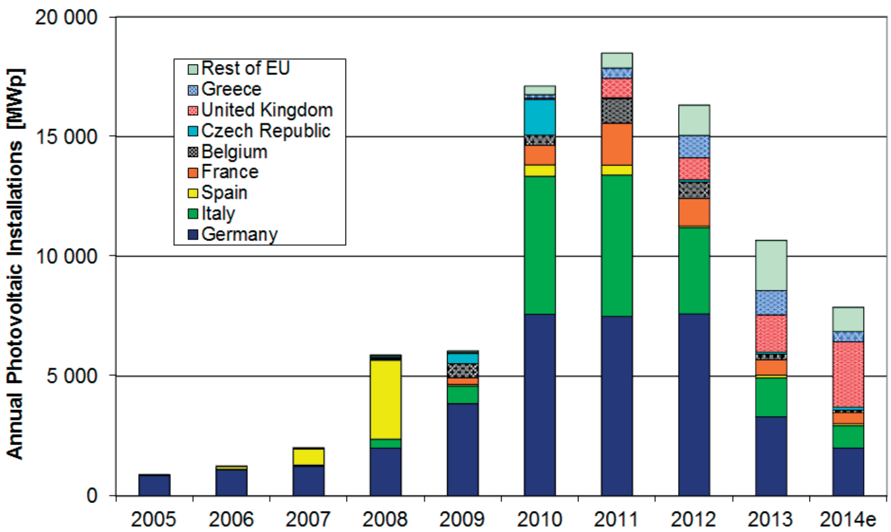

Fig. 6:
Annual installations in EU + CCs
(data source: [Epi 2014], [Eur 2014] and own analysis)

steep drop in new installations from 2011 to 2013 more than halved these local jobs and with them the positive effect on the local European economy.

The following sections describe market development in some EU Member States, as well as in Switzerland and Turkey.

2.2.1 Austria

In 2013, Austria installed about 265 W of new PV systems and increased the cumulative capacity to 625 MW. The Ökostrom-Einspeisetarifverordnung 2012 (Eco-Electricity Act) is the regulation which sets the prices for the purchase of electricity generated by green power plants. In addition, there is an investment subsidy with a budget of EUR 26.8 million for 2014. Regardless of the size of the systems, a maximum of 5 kWp are supported with EUR 275/kWp for add-on and ground-mounted systems and EUR 375/kWp for building-integrated systems. Operators of PV systems larger than 5 kWp can choose to opt for the so-called net-parity tariff (Netzparitätstarif) for a period of 13 years. Since 1 January 2013, this option has only been available for systems on buildings.

2.2.2 Belgium

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

In Flanders, larger systems have the choice between an ecological investment subsidy or green certificates. The green electricity certificates are issued by the Flemish regulatory authority (VREG). There is a technology-dependent banding factor, which is set twice a year by the Flemish Energy Agency (VEA), so that one certificate is not for 1 MWh, but depends on the type of installation [Res 2014].

In Wallonia, a new scheme called Qualiwatt came into effect on 1 April 2013 [GoW 2013]. Green certificates with a value of EUR 0.065/kWh are only granted until the PV installation has been fully reimbursed, the maximum duration being 10 years. The value of green certificates in the Brussels Region is EUR 65 and for PV systems a multiplier of 1.32 has been in place since 2 August 2013.

In 2011, Belgian installations peaked with over 1 GW of new installations, before starting to decline in 2012 (685 MW) and 2013 (263 MW). At the end of 2013, cumulative installed capacity was over 3 GW [IEA 2014a]. About 7.7 % of Belgian households are already generating their own PV electricity, and PV power covered 2.8 % of the country's total electricity needs in 2013 [Cha 2014].

2.2.3 Bulgaria

In May 2011, a new Renewable Energy Source (RES) Act was approved. The new law fixed the FiT levels and resulted in new installations of around 135 MW in 2011 and 843 MW in 2012. Because of legal uncertainties, only 10 MW were installed in 2013. At the end of 2013, the total cumulatively installed capacity of PV systems was a little over 1 GW.

In March 2012, the Bulgarian Parliament voted on a revision of the RES Act, which was then published in the *State Gazette* in April [GoB 2012]. The most significant change was that the price at which electricity is purchased is no longer fixed at the date when the installation is completed, but at the date the usage permit is granted.

On 14 September 2012, the Bulgarian State Energy and Water Regulatory Commission (SEWRC) published the prices for the retroactive grid usage fee – in accordance with the Energy Act amendments adopted by the Bulgarian Parliament in July 2012 [GoB 2012a] – for access to the transmission and distribution grid. For PV systems commissioned after 1 April 2010 and in 2011, the fee amounted to 20 % of the FiT. For systems commissioned in the first half of 2012, the fee was 39 % of the FiT, for those commissioned between 1 July and 31 August 2012, the fee was 5 %, and after 1 September 2012, 1 % of the respective FiT applied [Sew 2012].

On 17 June 2013, the Bulgarian Supreme Administrative Court (SAC), in a final ruling, revoked the grid access fee for producers of electricity from renewable energy sources. However, due to administrative issues, revocation of the fee only applies to some of the photovoltaic installation categories [Res 2014].

From 1 July 2014 until 30 June 2015, new FiTs have come into force which are between 18 % and 40 % lower, ranging between BGN 211.81/MWh (EUR[15] 10.80/MWh) for systems smaller than 5kWp on rooftops and facades and BGN 131.36/MWh (EUR 67.16/MWh) for systems above 10 MW [Bpa 2014].

2.2.4 Denmark

The introduction of a net-metering system and high electricity prices of EUR 0.295/kWh resulted in 378 MW of PV systems being installed in Denmark in 2012. In addition, due to this rapid development, the regime was changed in November 2012 [GoD 2012]. Under current rules, full net metering is only

[15] Exchange rate: EUR 1.00 = BGN 1.956

possible within one hour of the electricity being produced. There is also an exemption of part of or the whole public service obligation (PSO), which every customer must pay. No PSO is charged for systems smaller than 50 kW, whereas for systems larger than 50 kW only the renewable energy surcharge part of the PSO is waived [Res 2014].

Installations connected to the grid on or after 11 June 2013 are eligible for a maximum reimbursement (bonus plus market price) of DKK 0.60/kWh (EUR[16] 0.080/kWh) during the first 10 years of operation, and DKK 0.40/kWh (EUR 0.054/kWh) being applicable for a further 10 years.

In addition, the Danish grid operator (Energinet.dk) can provide more support for electricity produced in PV-installations connected to the grid on or after 11 June 2013 for a pool of 20 MW per year for five years, as from 2013 [Res 2014].

2.2.5 France

In 2013, about 640 MW of new PV systems were installed in France, about one-third of the total in 2011 [IEA 2014a]. Total cumulative installed capacity increased to over 4.7 GW, including about 400 MW in the French Overseas Departments. Electricity production (continental France and Corsica) from PV systems was 4.45 TWh or 1.24 % of the national electricity demand [Cha 2014a].

At the moment, France has three different support schemes for photovoltaics. For systems up to 12 MWp there is a FiT which depends on the size and type of installation. The tariffs in the first half of 2014 varied between EUR 0.2794/kWh for full building integrated systems up to 9 kWp, EUR 0.1416/kWh for simplified building integrated systems up to 36 kWp, EUR 0.1345/kWh for simplified building integrated systems between 36 and 100 kWp, and EUR 0.0717/kWh for PV systems up to 12 MW not attached to a building. The degression coefficients are adjusted regularly depending on the number and capacity of grid connection requests approved in the previous quarter.

The second support scheme is a reduced VAT rate of 10 % for systems up to 3 kWp used to supply residential electricity. If the system is larger than 3 kWp, only the first 3 kWp are eligible for the reduced VAT rate.

PV power plants are eligible to apply for specific calls for tender.

2.2.6 Germany

In 2013, Germany saw a drastic reduction in new system installations compared to 2011 and 2012. The annual market shrank from 7.5 GW and 7.6 GW in 2011 and 2012 to about 3.3 GW in 2013 [Bun 2014]. A further decrease is expected for 2014 to less than 2 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 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 fact that the tariff for residential PV systems smaller than 10 kWp (October 2014: EUR 0.1265/kWh) is now below the electricity rate consumers are paying (EUR 0.289/kWh) makes an increase in self-consumption more attractive and is opening up new possibilities for the introduction of local storage [Bun 2014a, Une 2013]. Since 1 May 2013, the Kreditanstalt für Wiederaufbau has been offering low interest loans with a single repayment bonus of up to 30 % and a maximum of EUR 600/kW of storage for PV systems up to 30 kWp [KfW 2013]. The maximum repayment bonus is limited to EUR 3000 per system.

2.2.7 Greece

In 2009, Greece introduced a FiT scheme which started slowly until the market accelerated from 2011 onwards. In 2013, about 1 GW of new PV system capacity was installed, thereby increasing the total cumulative capacity to almost 2.6 GW at the end of that year. About 2.4 GW are installed in the Greek mainland and the rest on the islands. However, most of this increase took place during the first five months when almost 900 MW were installed.

On 10 May 2013, 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.

The Hellenic Transmission System Operator SA (HTSO) reported about 2 079 MW of grid-connected PV systems over 10 kW and 350 MW of rooftop PV systems up to 10 kW on the Greek mainland at the end of August 2014 [Hts 2014].

2.2.8 Italy

Italy connected more than 1.6 GW, increasing cumulative installed capacity to slightly over 18 GW by the end of 2013 [Gse 2014]. The Quinto Conto

[16] Exchange rate: EUR 1.00 = DKK 7.46

Energia (Fifth Energy Bill) was approved by the Italian Council of Ministers on 5 July 2012 [Gaz 2012]. The bill set the new half-yearly reductions in tariffs, and the annual expenditure ceiling for new installations was raised from EUR 500 million to EUR 700 million. In addition, a new requirement was introduced to register systems larger than 12 kWp. On 6 June 2013, Gestore dei Servizi Energetici (GES) announced that the bill's EUR 6.7 billion ceiling had been reached with 18.2 GW, of which 17.1 GW were already operational, and that the Quinto Conto Energia would cease within 30 days [Gse 2013a].

According to the Italian national grid operator TERNA, electricity from PV systems provided 19.65 TWh or 8.5 % of the total generated during the first nine months of 2014 [Ter 2014]. The highest monthly coverage was in August, when PV electricity provided 11.9 % of the Italian energy supply.

2.2.9 The Netherlands

Since 2011, the main incentive has been a net-metering scheme for small residential systems up to 15 kW and a maximum of 5000 kWh/year. For very small systems between 0.6 and 3.5 kW, a rebate fund totalling EUR 50.8 million supported the installation of about 315 MW with an investment subsidy of up to 15 % between 1 July 2012 and 15 August 2013. Systems larger than 15 kW are eligible for a premium tariff under the SEDplus scheme, for a maximum of 1000 full load hours per year [Sta 2014]. At the end of 2013, the total cumulative capacity of PV systems was 722 MW, providing 4.1 % of the final electricity usage [Cbs 2014]. In September 2014, the Dutch Organisation for Sustainable Energy announced that the Netherlands had reached 1 GW of installed PV capacity [Duu 2014].

2.2.10 Romania

The promotion of renewable electricity is based on a quota system, tradable certificates, and minimum and maximum prices. In 2012, the Romanian Parliament approved (law 134/2012) the Government Emergency Electricity Regulation (No. 88/2011), which both amended and supplemented the basic law (No. 220/2008) on the establishment of a support system for the promotion of energy from renewable sources [Mon 2008, 2011, 2012]. Electricity suppliers and producers are obliged to provide a certain number (or quota) of green certificates, which are allocated to the producers of electricity from renewable energy.

After a slow start in 2012, which saw about 46 MW being installed, the market grew more than 20-fold to 1.1 GW in 2013 [IEA 2014a]. PV installations which are connected to the grid in 2014 are eligible for three green certificates, half the number available in 2013. According to the national transmission operator Transelectrica, PV power plants supplying almost 1 GW were connected to the national grid while an additional 3.3 GW of capacity already had connection contracts at the end of September 2014 [Tra 2014].

2.2.11 Spain

Spain is still third in Europe with regard to the total cumulative installed capacity, at 5.3 GW[17]. Most of this capacity was installed in 2008 when the country was the largest market, with over 3.3 GW [IEA 2014a]. This was more than twice the expected capacity and was due to an exceptional race to install systems before the autumn of 2008, when the Spanish Government introduced a cap of 500 MW on annual installations. A revised decree (Royal Decree 1578/2008) set considerably lower FiTs for new systems and limited the annual market to 500 MW, with the provision that two-thirds are rooftop-mounted and there are no longer any free-field systems [Bol 2008]. These changes resulted in a sharp fall in new installations.

In January 2012, the Spanish Government passed the Royal Decree 1/12 [Bol 2012], which suspended the remuneration pre-assignment procedures for new renewable energy power capacity, affecting about 550 MW of planned solar PV installations. The justification given for this move was that, until then, Spain's energy system had amassed a EUR 24-billion power-tariff deficit; it is also argued that the special regime for renewable energy was the main reason. However, for over a decade, the Spanish Government has prevented utilities from charging consumers the true cost of electricity. Instead of allowing utilities to increase rates every time electricity generation costs increased (due to rising coal or natural gas costs, inflation or to changes in energy or environmental policy, for example), the government allowed them to create a scheme similar to a deferral account, whereby they could recover shortfalls in any individual year from revenues generated in subsequent years.

By January 2007, the European Commission had already opened an in-depth investigation to examine the potential aid to large and medium-sized companies and to electricity distributors in Spain in the form of artificially low regulated industrial tariffs for electricity [EC 2007]. In 2005, these regulated tariffs led to a deficit of EUR 3.8 billion in the Spanish electricity system, and amounted to almost EUR 9 billion in 2007, a time when payments under the special regime for renewable energy were still limited.

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[16] 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 previous PV status reports.

Despite the Royal Decree 1/12 and other measures taken in 2012 and 2013, including the increase in electricity prices and introduction of new taxes on electricity generation from the beginning of 2013, the tariff deficit increased further in 2012 and 2013. Despite the government's intention to secure a zero deficit in 2013, the tariff deficit in that year was over EUR 3.6 billion, reaching a cumulative amount of EUR 30 billion or 3 % of GDP [Joh 2014].

Further attempts to end the tariff deficit led to the Electricity Act 24/2013 and the Ministerial Order IET/1045/2014 of 16 June 2014, which implements and supplements Royal Decree 413/2014 of 6 June 2014, regulating the production of electricity from renewable energy sources, cogeneration and waste. Together with Royal Decree Act 9/2013 of 12 July 2013, adopting urgent measures to ensure the financial stability of the electricity system, these measures form a complex set of regulations for the remuneration of electricity produced from renewable energy sources. Amongst other measures, the Electricity Act introduced a levy on the self-consumption of electricity produced by the consumer.

In 2013, new PV systems were installed with a capacity of 118 MW. In the same year, electricity generated from PV systems contributed 8.3 TWh or 3.2 % of the Spanish demand.

2.2.12 Switzerland

In 2013, about 320 MW of PV systems were installed in Switzerland, increasing the total capacity to 756 MW. After a 40 % price decrease in 2012, prices for turnkey systems fell by a further 12 % in 2013 [Pho 2014]. A revised energy law came into force on 1 January 2014. The necessary implementation rules came into force on 1 April 2014, giving electricity producers the right to self-consume the electricity they produce, regardless of the technology [GoS 2014]. New installed PV systems with a capacity of between 2 and 10 kW will receive an investment subsidy instead of the FiT. System owners of PV systems with a capacity between 10 and 30 kW can choose between an investment subsidy or the FiT. Surplus electricity from systems with an investment subsidy can be sold to the grid operator at market prices between CHF 0.05 and 0.09/kWh (EUR[18] 0.042 and 0.075/kWh).

2.2.13 United Kingdom

The United Kingdom introduced a new FiT scheme in 2010 which led to the installation of approximately 55 MW that year, 814 MW in 2011, 924 MW in 2012, and over 1.5 GW in 2013. Overall cumulative capacity reached almost 3.4 GW by the end of 2013. In Q3, cumulative installed PV capacity exceeded 5 GW.

This steep increase was caused by the announcement in February 2011 of a fast-track review of large-scale projects by the Department of Energy and Climate Change (DECC), which led to a rush to complete these projects in the first half of 2011 [DEC 2011]. A second push occurred towards the end of the year to meet the 12 December 2011 deadline, when DECC planned to decrease the residential tariff by about 50 % as a result of another fast-track consultation. However, this decision was contested in court and the tariffs were only changed on 1 April 2012. The average reductions were 44 % to 54 % for systems smaller than 50 kWp and 0 % to 32 % for systems over 50 kWp. In November 2012, a further reduction of 3.5 % was implemented for systems smaller than 50 kWp, whereas there was no reduction for larger systems because hardly any were installed between May and July 2012. Larger systems which start operation up until April 2015 are eligible for renewable obligation certificates (ROC). The number of ROCs per MWh produced has been gradually reduced to reflect falling system costs. From April 2015, larger PV systems will be eligible for a market premium using a contract of difference.

Since 2012, the Energy and Climate Change Minister Greg Barker has repeatedly stated his desire to see the UK solar market reach 22 GW by 2020.

2.2.14 Other European countries 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), 18.6 MW of PV systems were installed at the end of 2013. As of September 2014, this number had increased to 30.2 MW installed with an additional 25.5 MW, which already have signed contracts but are not yet installed [Hro 2014].

Despite high solar radiation, solar PV system installation in **Portugal** has grown very slowly, reaching a cumulative capacity of 281 MW by the end of 2013.

After two years of rapid growth, the **Slovakian** market fell by over 90 % with only 29 MW and 10 MW new installations in 2012 and 2013. The total capacity of 532 MW is more than three times the original 160 MW capacity target for 2020, published in the National Renewable Energy Action Plan in 2010. As of February 2011, support was limited to applications for systems smaller than 100 kW, and as of 1 July 2013, support has been limited to systems up to 30 kW that are placed on buildings.

In March 2010, the **Turkey**'s Energy Ministry unveiled the 2010-2014 Strategic Energy Plan. One of the government's priorities is 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 legisla-

[18] Exchange rate: EUR 1 = CHF 1.20

tion which defines new guidelines for FiTs. The FiT is 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 will increase 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 photovoltaic 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 (EPDK). However, no licence for PV installations above 1 MW had been approved by the end of 2013. There was some activity in the small-scale PV market as projects below 1 MW do not need a licence – about 6 MW were installed in 2013 [IEA 2014a]. At the end of 2013, around 20 MW of grid-connected and stand-alone systems were estimated to be installed cumulatively.

In 2013, once again **Ukraine** saw impressive growth and almost doubled its capacity with over 240 MW of new installed systems to 616 MW by the end of that year. In July 2012, the Ukrainian Parliament held the first reading of a bill to simplify households' access to the feed-in scheme. The bill included a reduction in FiTs of 16 % to 27 %, depending on the type of installation; this measure was adopted in February 2013 and came into force on 1 April 2013. Since then, tariffs have been adjusted on a monthly basis. However, the country's political instability is severely impacting the further development of the sector.

2.3 Americas

2.3.1 Canada

In 2013, the Canadian market saw an increase of about 50 % with 445 MW of new PV installations, driven by a doubling of large-scale installations [IEA 2014a]. Total cumulative installed PV capacity increased to over 1.2 GW. Most of the systems are installed in Ontario, which has a feed-in tariff programme. Most other provinces have a net-metering scheme. Ontario's Long-term Energy Plan sets a target of 10.7 GW of non-hydro renewable energy sources by 2021.

2.3.2 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.

In 2013, about 60 MW of new PV systems were installed thereby increasing the total cumulative PV system capacity to 112 MW [IEA 2014a]. The IEA Medium-Term Renewable Energy Market Report 2014 forecasts a cumulative PV capacity of 2 GW by 2020 [IEA 2014].

2.3.3 United States of America

With over 4.7 GW of newly installed PV capacity, the United States had reached a cumulative PV capacity of 12.1 GW by the end of 2013. Utility PV installations increased by over 50 % compared to 2012, and were the largest segment with 2.8 GW in 2013. The top ten States – California, Arizona, North Carolina, Massachusetts, New Jersey, Hawaii, Georgia, Texas, New York and Colorado – accounted for 90 % of the US PV market, and California alone had a market share of 55 % [Sei 2014]. The estimated market growth for 2014 is around 30 %.

In the first half of 2014, PV systems represented 55 % of the nominal new electricity capacity in the USA [Sei 2014a]. PV projects based on PPAs, with a total capacity of 14.8 GW, were under contract in Q3 2014, and 2.5 GW of these projects have already been financed and are under construction. If those projects at an earlier development stage are included, the pipeline stands at more than 24 GW.

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 & 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.

2.3.4 Emerging markets

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 renewable energy sources, the government awarded PPAs to six solar PV projects totalling 20 MW. By the end of 2013, about 20 MW (10 MW off-grid) of PV systems had been installed. According to the renewable energy country attractiveness indicator, the Argentinian Government has set a 3.3 GW target for PV installations by 2016 [Ern 2011].

At the end of 2013, **Brazil** had about 170 MW of cumulative installed capacity of PV systems. In April 2012, the board of the National Agency of Electric Energy (ANEEL) approved new rules to reduce barriers to installing small distributed generation capacity. The rules apply to generators that use subsidised sources of energy (hydro, solar, biomass, co-generation and wind). For the reserve energy auction on 31 October 2014, ANEEL set a cap price of BRL 262.0 /MWh (EUR[19] 84.5/MWh) for solar energy [Ane 2014]. For that auction, 400 preliminary applications for PV power projects with a combined capacity of 10.8 GW were accepted.

In February 2012, the President of **Chile** announced a strategic energy plan for achieving 20 % of non-conventional renewable energy by 2020. Legislation to reach this target is currently under consideration. In the first quarter of 2012, the first MW-size PV system was installed in the northern Atacama Desert. It is estimated that about 12 MW of PV systems (7 MW grid-connected) had been installed by the end of 2013.

In June 2014, over 180 MW of PV systems were operational and 550 MW of PV systems were under construction. Over 10.5 GW of projects were presented to Chile's Environmental Assessment Service (SEIA) for approval.

As early as 2007, the **Dominican Republic** passed a law promoting the use of renewable energy and set a target of 25 % renewable energy share by 2025 [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 (CDEEE) signed various PPAs totalling 170 MW in 2011 and 2012, no information about the operation of significant capacities can be found. Since then, various multi-MW projects have been announced, but to date none are operational. It is 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 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. No significant additions were reported during 2013. The National Photovoltaic Household Electrification Program, launched in 2013, aims to supply PV electricity to 500 000 households by means of 12 500 solar systems by 2016.

2.4 Africa

Despite Africa's vast solar resources and the fact that in large areas the same photovoltaic panel can produce on average twice as much electricity in Africa than in Central Europe, there has been only limited use of solar photovoltaic electricity generation up until now. According to the latest JRC resource study, solar PV electricity is now the cheapest electricity option for more than one-third of the African population [Bar 2013]. Until recently, the main application of PV systems in Africa was in small solar home systems 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.

Overall, the (documented) capacity of installed PV systems had risen to more than 600 MW by the end of 2013, a tenfold increase compared to 2008. In 2014, the installed capacity is expected to more than double. Currently, the two biggest markets are South Africa and Algeria. All African countries are either **potential or emerging markets** and some are mentioned below. Current African PV targets for 2020 are in excess of 10 GW.

2.4.1 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. Three rounds have already taken place: in 2011 (630 MW), 2012 (420 MW), and 2013 (450 MW). The fourth one closed in August 2014. The overall target is 3.725 GW and that for solar PV is 1.45 GW. In the first three bidding rounds, 1.5 GW of solar PV projects were allocated to the preferred bidders. Between the first round (closing date: 4 November 2011) and the third round (closing date: 29 October 2013) the average bid price fell from ZAR 2.65/kWh (EUR[20] 0.265/kWh) to ZAR 0.88/kWh (EUR[21] 0.063/kWh). According to WikiSolar, over 500 MW utility-scale solar plants were operational in June 2014 [Wik 2014].

[19] Exchange rate: EUR 1 = BRL 3.10
[20] Exchange rate 2012: EUR 1 = ZAR 10
[21] Exchange rate 2014: EUR 1 = ZAR 14

Due to the country's local content rules, more and more manufacturers along the solar value chain are setting up plants in South Africa. The following is a non-exhaustive list of industry activities.

Back in 1996, Tenesol Manufacturing, a subsidiary of Tenesol and part of Total and the EDF Group, established a module manufacturing plant with 20 MW capacity in Cape Town. In the meantime, it has become part of SunPower and now has a manufacturing capacity of 85 MW.

Setsolar was set up in Cape Town in 2007. The company manufactures and distributes solar modules and other system components. Its manufacturing capacity is estimated at 20 MW.

In 2011, Solaire Direct Technologies (Pty) Ltd started module manufacturing in Cape Town. With a production capacity of about 36 MW, it manufactures OEM modules for different companies as well as its own brand. It signed an OEM contract (120 MW) with ReneSola in 2013 [Sol 2013].

In 2013, ARTSolar opened a module factory in Durban with a capacity of 75 MW. The company manufactures OEM modules for different companies as well as its own brand [Art 2013].

Early in 2014, JA Solar (PRC) announced the establishment of a joint venture with Powerway PV SA (Pty) Ltd. to build a solar-module manufacturing facility in Port Elizabeth [Jas 2014]. Production was scheduled to begin in the second quarter of 2014, with the plant targeting an initial annual capacity of 150 MW; it has the option for an expansion to 600 MW. According to local information, the plant will only frame laminates at the outset.

In February 2014, Photovoltaic Technology Intellectual Property (Pty) Ltd. (PTiP) officially launched its pilot production line for the manufacturing of CIGS thin-film solar modules. Equipment supplied by German company Singulus [Sin 2014].

In March 2014, Powerway PV SA, part of Powerway Renewable Energy Co. Ltd (PRC), a global solar-farm builder/system integrator, and Sungrow (PRC), the third largest inverter company in 2012, announced the setting up of a manufacturing facility in the Coega Development Corporation in Port Elizabeth [Pow 2014].

At the end of June 2014, SMA Solar Technology AG (SMS) commissioned an inverter factory for local production in Cape Town [Sma 2014]. It consists of a production line, storage facilities and a test centre for central inverters.

In August 2014, JinkoSolar Holding Co. Ltd. announced the opening of a 120-MW module factory in Cape Town [Jin 2014].

2.4.2 Emerging markets

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 feed-in tariff regimes, one for systems between 1 and 5 MW and one for systems larger than 5 MW. It is 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. In 2014, new installations of around 319 MW should become operational.

Cape Verde's Renewable Energy Plan (2010 to 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. By the end of 2012, 7.5 MW of centralised grid-connected PV systems had been installed. In addition, there are a number of smaller off-grid and grid-connected systems. About 340 MW of PV systems are required to achieve the 2020 50 % renewable energy target.

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 the Ministry of Water and Energy, at the end of 2013, the country had about 826 000 solar home systems as well as solar systems for 345 rural health centres and 190 schools [MWE 2014]. Press reports confirmed the Ethiopian Electric Power Corporation (EECPo) approved three solar plants with a capacity of 300 MW in the eastern region of the country [Ven 2013].

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 solar home systems and a few off-grid systems providing an estimated 5 MW installed in the country. In 2012, Episolar of Canada signed a PPA with Ghana's second largest utility, the Electricity Company of Ghana, for a 50-MW PV plant, with the option of increasing the overall project size to 150 MW [Epi 2012]. News about closing the financing has yet to be made available. In December 2012, the UK's Blue Energy announced that it had agreed a 20-year PPA with Ghana's Public Utilities Regulatory Commission for a 155-MW PV plant in Nzema, to be operational by 2015 [Blu 2012]. As a follow-up, in March 2014, the Ghana Government announced that Mere Power Nzema Limited (MPNL), in partnership with Mere Power UK and Blue Energy, both UK-based renewable energy firms, will build a 155-MW photovoltaic solar plant at Asiamah in the Western Region [GoG 2014]. In May 2013, the Volta River Authority (VRA) inaugurated its first solar power plant at Navrongo, with a capacity of 2.5 MW. VRA plans to install a total of 14 MW by 2015. Besides this plant, about 2 MW of smaller grid-connected PV capacity and 0.8 MW of small solar home systems were operational at the end of 2013.

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 solar home systems. 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 solar home systems, telecommunication applications, diesel-PV hybrids and the few grid-connected systems will be about 20 to 25 MW at the end of 2014.

The **Kingdom of Morocco's** solar plan was introduced in November 2009, with the aim of establishing 2000 MW of solar power by 2020. To implement this plan, the Moroccan Agency for Solar Energy (MASEN) was founded in 2010. Solar electricity technologies, concentrating solar thermal power (CSP) and PV will all compete openly. Earlier in 2007, the National Office of Electricity (ONE) 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 (PERG), and about 1 to 2 MW of grid-connected systems.

Two companies in Casablanca are producing PV modules – Droben Energy, a subsidiary of the Spanish Droben company, with 5MW, and Cleantech with 15 MW capacity.

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. According to the International Renewable Energy Agency (IRENA), the current targets are 18 % and 20 % of electricity from renewables by 2025 and 2030, respectively [IRE 2012]. Solar PV is set to contribute 300 MW by 2015 and 4000 MW in 2025.

Within the framework of the renewable energy and energy efficiency partnership between Nigeria and Germany established in 2008, Germany agreed to bankroll the installation of 500 MW of PV systems until 2017.
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.

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]. The SREP calls for a cumulative installed PV capacity of 60MW by 2017 and 120 MW by 2020. Cumulative PV capacity is expected to reach 10 MW by the end of 2014.

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 [Aes 2013]. It is estimated that a total PV capacity of 5 to 6 MW had been installed by the end of 2013. 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.

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. 7). 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 between USD_{2014} 4 and 4.5/Wp. This occurred despite the fact that manufacturing technology continued to improve and companies significantly scaled up their production. The reason or this was the expanding markets in Germany and Spain, where the FiTs enabled project developers to be profitable at that price. This was coupled with the temporary shortage of polysilicon between 2004 and 2009, which limited silicon 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.

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].

PV system prices have followed the lowering of module prices but at a slower pace. This becomes obvious by looking at the PV module share in the system price, which shifted from almost 70 % in 2008 to less than 50 % in 2014.

Despite the fact that there is a global market for the hardware components of a PV system, e.g. modules, inverters, cables, etc., and that prices are very similar worldwide, the prices for installed PV systems still vary significantly. 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 – this is open up new opportunities for photovoltaics in a growing number of countries to become one of the major electricity providers in the near future.

3.1 Levelised Cost of Electricity

A common measure for the comparison of power-generation technologies is the concept of the Levelised Cost of Electricity (LCOE)[22]. 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

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

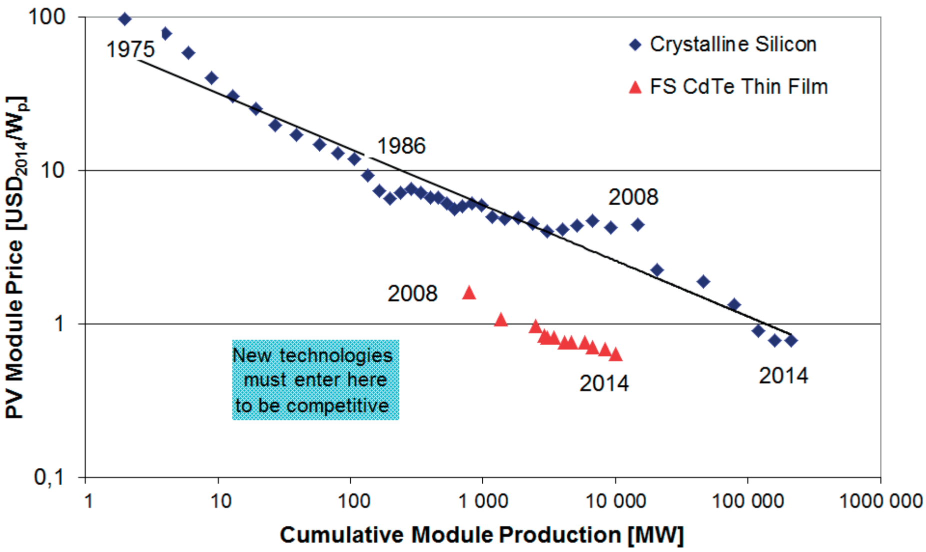

Fig. 7: Price-experience curve for solar modules (data source: Bloomberg New Energy Finance and PV News)

of the energy-generating system, including all the costs over its lifetime: initial investment, operations and maintenance, 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 renewable energy sources (Fig. 8). 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.

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 renewable energy sources and optimised integration technology options [Hir 2013 and references, Uec 2013].

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.

3.2 LCOE of residential grid-connected PV systems

Over the last decade, prices for residential grid-connected PV systems have decreased significantly, as shown in Fig. 9. The increase in PV system prices in Japan, between 2007 and 2010, came from changes in exchange rates; in the local currency the prices fell further.

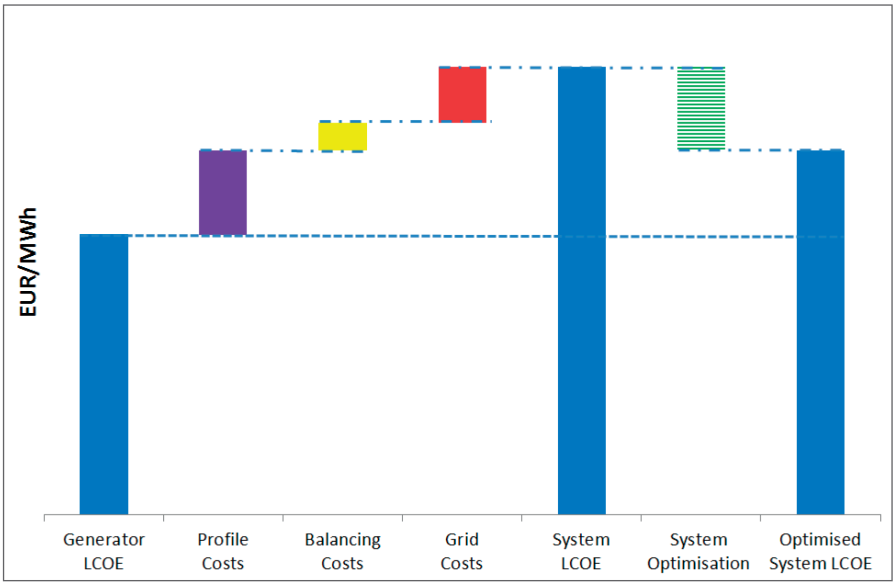

Fig. 8: System LCOE

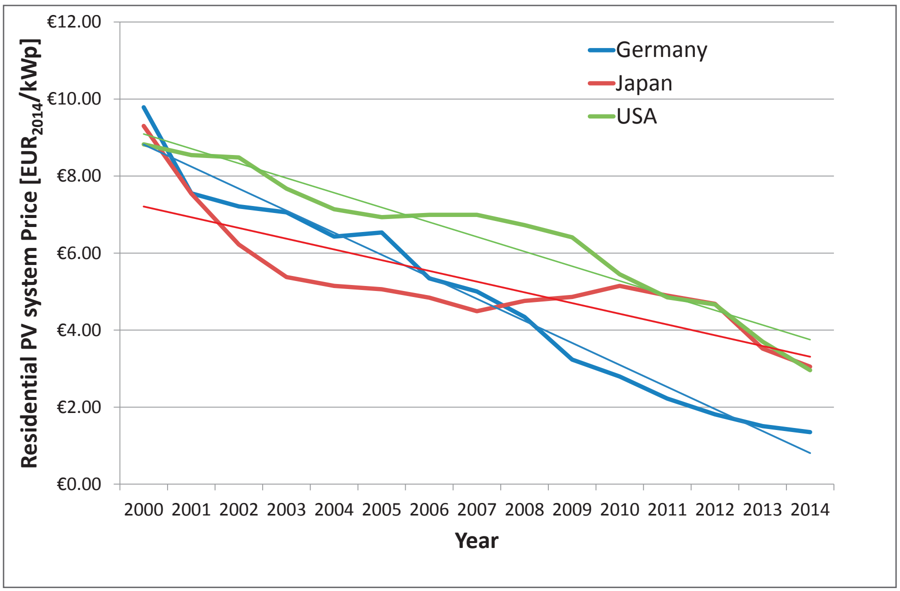

Fig. 9: Residential PV system price development over the last decade (data sources: IEA PVPS, BSW, DoE SunShot Initiative, Eurostat, OECD key economic data)

As shown in a growing number of countries, electricity production from residential PV solar systems can be cheaper than residential electricity prices, depending on the actual electricity price and the local solar radiation level. In the case of a PV system size that generates as much electricity as the customer uses over a year, the actual consumption during the time of generation is in general only around 30 % if no demand shifting or local storage is applied. Therefore, 70 % 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.

In October 2014, the worldwide average price of a residential system without tax was given as USD 1.84/Wp (EUR 1.45/Wp) about 15 % higher than in Europe with EUR 1.27/Wp or Australia [Pvi 2014, Sol 2014]. Taking the European price and adding a surcharge of EUR 0.13/Wp for fees, permits, insurance, etc., an installed PV system costs EUR 1400/kWp without financing and VAT. The influence of the European VAT rates on investment costs and LCOE

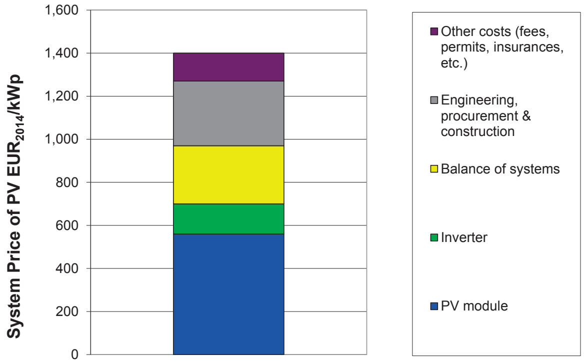

Fig. 10: Price breakdown of residential PV system (data source: own analysis)

are shown in the European Cost Maps [Hul 2014]. The breakdown of costs is depicted in Fig. 10.

As shown in Tables 1 and 2, already at 5 % return on investment (ROI) the financing costs are the largest single cost factor. Together with fees and permit costs, they comprise one-third of the electricity-generation costs from a residential PV system for the first 20 years. The influence of financing is shown in Figs. 11 and 12 for low-risk financing at 3 % and an average investor rate of 10 %. The share of financing costs more than doubles from about 18 % to over 44 %. Therefore, reasonable financing is key to low-cost photovoltaic electricity.

Depending on the actual radiation level, the 2% operation, maintenance and repair (O&M)[22] costs are a main cost factor besides financing costs. The O&M costs cover the foreseeable repairs and exchange costs of components like the inverter, as well as the annual degradation of the solar modules as specified by the manufacturers. Adding a conservative safety margin of 1.2 EUR cent/kWh on top of the 2.8 EUR cent /kWh results in an electricity price of 4.0 EUR cent/kWh after the 20-year financial payback period.

In 2014, the average residential electricity rate in Australia is about AUD 0.24/kWh (EUR 0.169/kWh), but for customers with peak tariffs this can increase to AUD 0.39/kWh (EUR 0.27/kWh) between 14.00 and 20.00, which is a good match with PV electricity generation. The average European residential electricity price given by Eurostat for the second semester of 2013 was EUR 0.201/kWh, higher than PV-generated electricity for the lower ROI financing options, which are more realistic for

[22] The O&M costs are 2 % higher than in other analyses. This is to reflect the fact that labour costs related to O&M activities have not decreased like the hardware components.

Table 1: LCOE of PV-generated electricity for residential systems with a system price of EUR 1400/kWp (excluding VAT, because the differences in the various countries are too large), 1.5 % O&M cost, an annual generation of 1000 kWh/kWp/year and financial lifetimes of 20 years

	Price [EUR/kWp]	LCOE Product [EURct/kWh]	LCOE Capital [EURct/kWh]			LCOE O&M 2 % [EURct/kWh]	LCOE Total [EURct/kWh]		
Return on investment		0 %	3 %	5 %	10 %		3 %	5 %	10 %
PV module	560	2.80	0.85	1.48	3.18	1.12	4.77	5.40	7.10
Inverter	140	0.70	0.21	0.37	0.79	0.28	1.19	1.35	1.77
Balance of systems	270	1.35	0.41	0.71	1.53	0.54	2.30	2.60	3.42
Engineering, procurement & construction	300	1.50	0.46	0.79	1.70	0.60	2.56	2.89	3.80
Other (fees, permits, insurances...)	130	0.65	0.20	0.34	0.74	0.26	1.11	1.25	1.65
Total	1400	7.00	2.14	3.70	7.95	2.80	11.94	13.50	17.70

Table 2: LCOE of PV-generated electricity for residential systems with a system price of EUR 1400/kWp (excluding VAT, because the differences in the various countries are too large), 2 % O&M costs, an annual generation of 1300 kWh/kWp/year and a financial lifetime of 20 years

	Price [EUR/kWp]	LCOE Product [EURct/kWh]	LCOE Capital [EURct/kWh]			LCOE O&M 2 % [EURct/kWh]	LCOE Total [EURct/kWh]		
Return on investment		0 %	3 %	5 %	10 %		3 %	5 %	10 %
PV module	560	2.15	0.66	1.14	2.45	0.86	3.67	4.15	5.46
Inverter	140	0.54	0.16	0.28	0.61	0.22	0.92	1.04	1.37
Balance of systems	270	1.04	0.32	0.55	1.18	0.41	1.77	2.00	2.63
Engineering, procurement & construction	300	1.15	0.36	0.61	1.31	0.47	1.97	2.23	2.93
Other (fees, permits, insurances...)	130	0.50	0.15	0.26	0.57	0.20	0.85	0.96	1.27
Total	1400	5.38	1.65	2.85	6.12	2.16	9.18	10.38	13.65

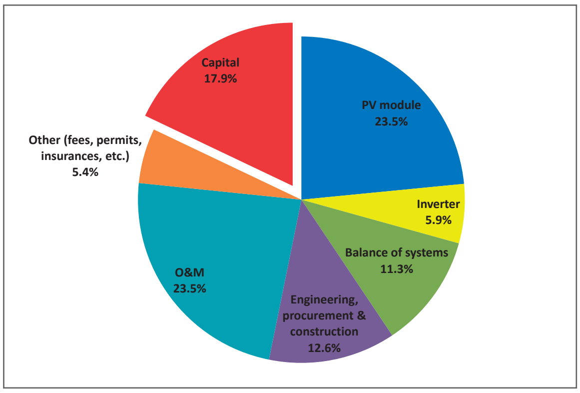

Fig. 11: LCOE cost shares for 3 % ROI

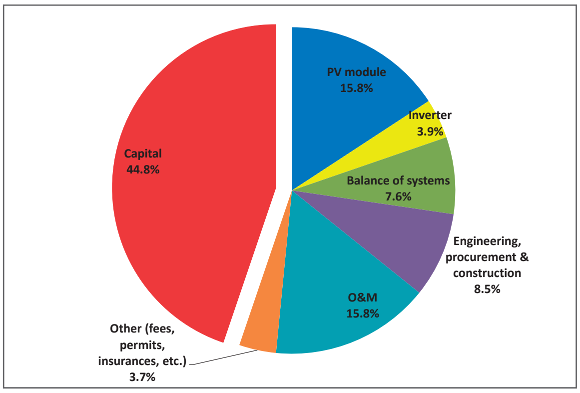

Fig. 12: LCOE cost shares for 10 % ROI

private consumers [Est 2014]. Cyprus, Denmark and Germany had the highest prices with EUR 0.294/kWh, EUR 0.292/kWh and EUR 0.248/kWh, respectively. In October 2014, the prices of Japan's largest utility Tokyo Electric Power Company (TEPCO) were JPY 19.43/kWh (EUR[24] 0.141/kWh) for the first 120 kWh per month, JPY 25.91/kWh (EUR 0.188/kWh) for everything above 120 kWh and below 300 kWh per month, and JPY 29.93/kWh (EUR 0.217/kWh) for every kWh above 300 kWh per month [Tep 2014]. In addition, customers pay a demand charge between JPY 280.80 (EUR 2.04) per month for 11kW and up to JPY 1684.80 (EUR 12.21) for a 66kW connection. In August 2013, a fuel surcharge of JPY 1.89/kWh (EUR 0.014/kWh) was added [Tep 2013].

Without support, the profitability of a solar PV system depends primarily on the owner's self-consumption, as less energy has to be purchased from the utility. In the case of a PV system size that generates as much electricity as the customer uses over a year, the actual consumption during the time of generation is in general only around 30 % if no demand shifting or local storage is applied. Therefore, 70 % of the generated electricity has to be sold to the grid. The question is what kind of pricing should be used – contract, wholesale or day-ahead prices.

[24] Exchange rate: EUR 1 = JPY 138

As an example, Table 3 shows the price at which surplus electricity has to be sold in Australia, Cyprus, Germany or Japan to break even with an ROI of 3 %. The average annual electricity consumption is 6600 kWh/year for Australia, 5200 kWh/year for Cyprus, 3500 kWh/year for Germany and 5500 kWh/year for Japan.

The first option for improving profitability is to increase self-consumption by demand shifting and using electrical appliances like the washing machine or dishwasher during the day when the sun shines. Another option is to use the difference between the necessary selling price of PV electricity and the household retail price to invest in local storage options, be they residential or community-owned. However, at the moment electricity storage is still a relatively expensive option, with the price of electricity from storage at EUR 0.18 to 0.21/kWh, which has to be added to the PV LCOE. The current investment costs for a residential battery storage system are roughly equally divided between the batteries and the electronic control components. In the future, it is very likely that the solar inverter will include large parts of the necessary electronics, thereby lowering the costs significantly.

A 2012 business analysis for electric vehicles by McKinsey showed that the 2012 price of lithium-ion batteries in the range USD 500 to 600/kWh (EUR 385 to 460/kWh) storage capacity could fall to USD 200/kWh (EUR 155/kWh) storage capacity by 2020 [Hen 2012]. Lithium-ion batteries have an average of 5000 cycles, which currently corresponds to a net kWh price of USD 0.10 to 0.12/kWh (EUR 0.077 to 0.093/kWh) and should fall to USD 0.04/kWh (EUR 0.03/kWh) by 2020.

According to various consultancy reports, the electricity storage market is expected to grow 10-fold over the next five years and exceed EUR 2 billion by 2017. This market development, together with a further retail price increase and a PV system price reduction, could lower the LCOE of a PV system, including storage, below average European electricity retail prices and make PV electricity the lowest cost option for more than 230 million Europeans within the next five years.

Table 3: Necessary selling price of PV electricity to break even with a system price of EUR 1400/kWh (excluding VAT), 2 % O&M cost, ROI of 3 % and a 20-year financial payback

	Without PV system	100 % from PV system	30 % from PV system
Australia			
Purchase from utility (kWh)	6 600	4620	4620
Own PV electricity use (kWh)		1980	1980
PV electricity generation costs at 1500 kWh/kWp (EUR)		528 00	158 40
Utility bill (EUR 0.169/kWh)	1 115.40	780 78	780 78
Necessary selling price of PV electricity to break even at 1500 kWh/kWp (EUR/kWh)		0.042	
Saving (EUR)			176.22
Cyprus	5200	3640	3640
Own PV electricity use (kWh)		1560	1560
PV electricity generation costs at 1 600 kWh/kWp (EUR)		390 00	117 00
Utility bill (EUR) at 0.248 EUR/kWh	1 289.60	902 72	902 72
Necessary selling price of PV electricity to break even at 1600 kWh/kWp (EUR/kWh)		0.001	
Saving (EUR)			269 88
Germany	3500	2450	2450
Own PV electricity use (kWh)		1050	1050
PV electricity generation costs at 1000 kWh/kWp (EUR)		416 50	124 95
Utility bill (EUR) at 0.292 EUR/kWh	1 022.00	715 40	715 40
Necessary selling price of PV electricity to break even at 1000 kWh/kWp (EUR/kWh)		0.045	
Saving (EUR)			181 65
Japan	5500	3850	3850
Own PV electricity use (kWh)		1650	1650
PV electricity generation costs at 1000 kWh/kWp (EUR)		654 50	196 35
Utility bill (EUR) at TEPCO tariff	1 098.42	717 27	717 27
Necessary selling price of PV electricity to break even at 1000 kWh/kWp (EUR/kWh)		0.071	
Saving (EUR)			184 80

3.3 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 2012, 11.1 GW of utility-scale PV power plants were operational worldwide.

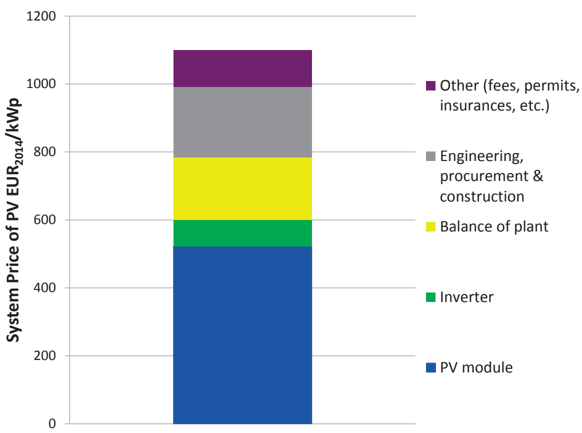

Fig. 13: Price breakdown of utility-scale PV system

Due to the plant size, which is currently up to 250 MW, the cost structure and LCOE is quite different from that of residential PV systems. Fig. 13 shows the average cost breakdown in competitive markets. The actual cost breakdown differs from project to project.

Already in 2010, Ken Zweibel published an analysis of how discount rates influence the competitiveness of solar photovoltaic electricity generation [Zwe 2010]. He calculated that with a market size of 40 GW per year system costs of USD_{2010} 2.00/Wp (EUR_{2010} 1.54/Wp) should be possible. The 2014 market is expected to be above this, and current utility system prices at EUR 1100_{2014}/kWp (USD 1554_{2010}/kWp[25]) are well below this level.

Tables 4 and 5 show the LCOE from utility-scale PV systems at different radiation levels and ROI. As for residential systems, the financing cost are the single most important cost item for ROI greater than 5 %. Therefore, any measure to lower the financing costs, like production tax credits, has a significant impact on the overall LCOE.

[25] United States inflation - see: http://www.usinflationcalculator.com/inflation/historical-inflation-rates/

Table 4: LCOE of PV-generated electricity for utility-scale systems with a system price of EUR 1100/kWp, 2 % O&M costs, an annual generation of 1000 kWh/kWp/year and financial lifetimes of 20 years

	Price [EUR/kWp]	LCOE Product [EURct/kWh]	LCOE Capital [EURct/kWh]			LCOE O&M 2 % [EURct/kWh]	LCOE Total [EURct/kWh]		
Return on investment		0 %	3 %	5 %	10 %		3 %	5 %	10 %
PV module	525	2.63	0.80	1.38	2.98	1.05	4.48	5.06	6.66
Inverter	80	0.40	0.12	0.21	0.45	0.16	0.67	0.77	1.01
Balance of systems	185	0.93	0.28	0.48	1.05	0.37	1.48	1.78	2.35
Engineering, procurement & construction	205	1.03	0.31	0.54	1.16	0.41	1.75	1.98	2.60
Other (fees, permits, insurances...)	105	0.53	0.16	0.27	0.59	0.20	0.90	1.01	1.33
Total	1100	5.50	1.68	2.91	6.25	2.20	9.38	10.61	13.95

Table 5: LCOE of PV-generated electricity for utility-scale systems with a system price of EUR 1100/kWp, 2 % O&M costs, an annual generation of 1300 kWh/kWp/year and financial lifetimes of 20 years

	Price [EUR/kWp]	LCOE Product [EURct/kWh]	LCOE Capital [EURct/kWh]			LCOE O&M 2 % [EURct/kWh]	LCOE Total [EURct/kWh]		
Return on investment		0 %	3 %	5 %	10 %		3 %	5 %	10 %
PV module	525	2.02	0.62	1.07	2.29	0.81	3.44	3.89	5.12
Inverter	80	0.31	0.09	0.16	0.35	0.12	0.52	0.59	0.78
Balance of systems	185	0.71	0.22	0.38	0.81	0.28	1.21	1.37	1.80
Engineering, procurement & construction	205	0.79	0.24	0.42	0.89	0.31	1.34	1.52	2.00
Other (fees, permits, insurances...)	105	0.40	0.13	0.22	0.46	0.16	0.69	0.78	1.02
Total	1100	4.23	1.29	2.24	4.81	1.69	7.21	8.16	10.73

In early 2013, the PPA for the 50-MW solar power plant at Macho Springs (New Mexico), United States, made headlines when it was announced that the El Paso Electric Company would purchase the solar power at USD 57.90/MWh (EUR 44.54/MWh) from May 2014 onwards [NMR 2013, Wes 2013]. PV projects qualify for the federal energy investment tax credit (ITC) programme (30 %) and the Modified Accelerated Cost Recovery System depreciation (five-year MACRS). However, this extremely low PPA is only made possible by an additional 10-year New Mexico state production tax credit (PTC) which, according to New Mexico's Energy, Minerals and Natural Resources Department (EMNRD), adds another USD 27/MWh (EUR 20.77/MWh).

4 THE PHOTOVOLTAIC INDUSTRY

The PV industry consists of a long value chain from raw materials to PV system installation and maintenance. So far, the main focus has been on the solar-cell and module manufacturers, but there is also the so-called upstream industry (e.g. materials, polysilicon production, wafer production and equipment manufacturing) as well as the downstream industry (e.g. inverters, balance of system (BOS) components, system development, project development, financing, installations and integration into existing or future electricity infrastructure, plant operators, operation and maintenance, etc.). In the near future, it will be necessary to add (super)-capacitor and battery manufacturers as well as power electronics and IT providers to manage supply and demand and meteorological forecasts. The main focus in this report, however, is still on solar-cell, module and polysilicon manufacturers.

In 2013, the PV world market grew by 10 % in terms of solar cell production to almost 40 GW. The market for installed systems grew by more than 20 %, and values between 37 and 40 GW were reported by various consultancies and institutions. This mainly represents the grid-connected PV market since, to what extent the off-grid and consumer-product markets are included remains unclear.

In addition, the fact that some companies report shipment figures, some sales figures and others production figures adds to the uncertainty. An additional source of error stems from the fact that some companies produce fewer solar cells than solar modules, but the reporting does not always differentiate between the two and there is a risk that cell production is counted twice – first at the cell manufacturer and then again at the 'integrated' cell/module manufacturer. The difficult economic conditions contributed to the lowering in willingness to report confidential company data. Nevertheless, the figures show a significant increase in production, as well as a growing installation market.

Despite the fact that a significant number of companies filed for insolvency, scaled back or even cancelled their expansion projects, the number of new entrants in the field, notably large semiconductor or energy-related companies, overcompensated for this between 2008 and 2012. In 2013, no significant capacity increase was reported, but the first signs of a return to manufacturing capacity growth were visible in 2014 and could increase in 2015. However, the rapid changes in the sector and the difficult financing situation make any reasonable forecast for future capacity developments very speculative.

4.1 Technology mix

After the temporary silicon shortage between 2004 and 2008, silicon prices fell dramatically, as did the cost of wafer-based silicon solar cells. In 2013, their market share was close to 90 % and they became the main technology. Commercial module efficiencies range widely from 12 % to 21 %, with monocrystalline modules from 14 % to 21 %, and polycrystalline modules from 12 % to 18 %. The massive increases in manufacturing capacity for both technologies were followed by the capacity expansions needed for polysilicon raw materials.

In 2005, for the first time, the production of thin-film solar modules reached more than 100 MW per annum. Between 2005 and 2009, the compound annual growth rate (CAGR) of thin-film solar module production exceeded that of the overall industry, increasing the market share of thin-film products from 6 % in 2005 to 10 % in 2007 and from 16 % to 20 % in 2009. Since then, the thin-film share has declined slowly as the ramp-up of new production lines has not followed that of wafer-based silicon.

The majority of thin-film manufacturers remain silicon-based and use either amorphous silicon or an amorphous/microcrystalline silicon structure. Fewer companies use $Cu(In,Ga)(Se,S)_2$ as absorber material for their thin-film solar modules, and only a few use CdTe (cadmium telluride) or dye and other materials.

Concentrating photovoltaics (CPV) is growing at a fast pace, although from a low starting point. About 60 companies are active in the field of CPV development, the majority of them focusing on high-concentration concepts. Over half of them are located either in the United States (primarily in California) or Europe (mainly in Spain).

Within CPV, there is a differentiation according to concentration factors[26] and whether the system uses a dish (Dish CPV) or lenses (Lens CPV). The main parts of a CPV system are the cells, the optical elements and the tracking devices. The recent growth in CPV is based on significant improvements in all these areas, as well as in system integration. However, it should be pointed out that CPV is at the beginning of an industry learning curve, with considerable potential for both technical and cost

[26] High concentration > 300 suns (HCPV),
medium concentration 5 < x < 300 suns (MCPV),
low concentration < 5 suns (LCPV).

improvements. The most challenging task is to become cost-competitive with other PV technologies quickly enough in order to grow to reach factory sizes and thus benefit from economies of scale.

Despite the current small installed capacity, various consultancy companies predict that the CPV market will grow to 500 MW by 2015 and 1 GW by 2010 [Glo 2013, Str 2013].

The existing PV technology mix is a solid foundation for the future growth of the sector as a whole. No single technology can satisfy all the different consumer requirements, ranging from mobile and consumer applications, and the need for a few watts up to multi-MW utility-scale power plants. If material limitations or technical obstacles restrict the further growth or development of a single technology pathway, then the variety of technologies will be an insurance against any stumbling blocks in the implementation of solar PV electricity.

4.2 Solar-cell production[27] companies

More than 350 companies worldwide produce solar cells. The solar-cell industry has been very dynamic over the last decade, but the changes that have taken place since 2011 only provide a snapshot of the current situation, which can change in just a few weeks.

The following section gives a short description of the 20 largest companies, in terms of actual production/shipments in 2013. More information about other solar cell companies can be found in various market studies. The capacity, production or shipment data are from the annual reports or financial statements either of the respective companies or the references cited.

4.2.1 Yingli Green Energy Holding Co. Ltd. (China)

Yingli Green Energy (http://www.yinglisolar.com/) went public on 8 June 2007. The main operating subsidiary, Baoding Tianwei Yingli New Energy Resources Co. Ltd, is located in the Baoding National High-tech Industrial Development Zone. The company's operations include solar wafers, cell manufacturing and module production. According to the firm, production capacity reached 1.85 GW at the end of 2011. In its 2013 annual report, it reported that by the end of 2013 it had a capacity of ingots, wafers, cells and modules equivalent to 2.45 GW. In its financial statement, the company reported that in addition to its own cells, it was also purchasing cells from other suppliers. Total reported shipments of solar modules for 2013 were 3.2 GW. Solar-cell production is estimated at 2.2 GW for 2013.

In January 2009, Yingli acquired Cyber Power Group Ltd., a development-stage enterprise created to produce polysilicon. Through its principle operating subsidiary, Fine Silicon, the company started a trial production of solar-grade polysilicon in late 2009, and at the end of 2011 was still ramping up to a full production capacity of 3000 tonnes per year. However, the financial results indicate that the company has written off its investment in Fine Silicon and, according to other media reports, production has now closed down.

In January 2010, China's Ministry of Science and Technology approved an application to establish a national-level key laboratory in the field of PV technology development, the State Key Laboratory of PV Technology, at Yingli Green Energy's manufacturing base in Baoding.

4.2.2 Trina Solar Ltd. (China)

Trina Solar (http://www.trinasolar.com/) was founded in 1997 and went public in December 2006. The company has integrated product lines, from ingots to wafers and modules. In December 2005, a 30-MW monocrystalline silicon wafer product line went into operation. According to the company's annual report, the production capacity at the end of 2013 was 1.4 GW for ingots and wafers, 2.5 GW for cells, and 2.8 GW for modules, with a planned increase to 1.7 GW for ingots and wafers, 3.0 GW for cells and 3.5 GW for modules in 2014. Module and system deliveries of 2.58 GW were reported for 2013.

In January 2010, the company was selected by the Chinese Ministry of Science and Technology to establish a State Key Laboratory (SKL) to develop PV technologies within the Changzhou Trina PV Industrial Park. The laboratory is being established as a national platform for driving PV technologies in China. Its mandate includes research into PV-related materials, cell and module technologies and system-level performance. It will also serve as a platform for bringing together technical capabilities from the company's strategic partners, including customers and key PV component suppliers, as well as universities and research institutions.

4.2.3 JA Solar Holding Co. Ltd. (China)

JingAo Solar Co. Ltd. (http://www.jasolar.com) was established in May 2005 by the Hebei Jinglong Industry and Commerce Group Co. Ltd., the Australia Solar Energy Development Pty Ltd. and the Australia PV Science and Engineering Company. Commercial operations started in April 2006 and the company

[26] Solar-cell production capacities 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 cells are not counted.

went public on 7 February 2007. According to the company, at the end of 2013 the production capacity was 2.5 GW for cells, 1.8 GW for modules and 1 GW for wafers, with a capacity increase to 2.8 GW of solar cells and modules planned for 2014. Sales of 2.07 GW of solar products were reported for 2013.

4.2.4 JinkoSolar Holding Co. Ltd. (China)

JinkoSolar (http://www.jinkosolar.com/) was founded by Hongkong Paker Technology Ltd. in 2006. Starting from the upstream business, in 2009, the company expanded its operations across the solar value chain, including recoverable silicon materials, silicon ingots and wafers, solar cells and modules. In May 2010, it went public and is now listed on the New York Stock Exchange. According to the annual report, the company had manufacturing capacities of 1.5 GW for wafers and solar cells and 2 GW for solar modules at the end of 2013. A capacity increase to 2 GW for wafers and cells and 2.1 GW for modules is planned in 2014. For 2013, the company reported sales of about 1.94 GW (1.765 GW modules, 113 MW cells and 65 MW wafers).

4.2.5 Canadian Solar Inc. (China/Canada)

Canadian Solar Inc. (CSI) (http://www.canadiansolar.com/) was founded in Canada in 2001 and listed on NASDAQ in November 2006. CSI has established six wholly owned manufacturing subsidiaries in China, manufacturing ingot/wafer, solar cells and solar modules. According to the company, at the end of 2012 it had 216 MW of ingot and wafer capacity, 1.5 MW cell capacity and 2.4 GW module manufacturing capacity (2.1 GW in China and 330 MW in Ontario, Canada). For 2013, the company reported sales of 1.74 GW of

China and 330 MW in Ontario, Canada). For 2013, the company reported sales of 1.74 GW of modules and 157 MW of systems. However, no cell production figure was given, which must be lower because it states in its financial reports that it buys cells from other manufacturers.

4.2.6 First Solar LLC (USA/Germany/Malaysia)

First Solar LLC (http://www.firstsolar.com) is one of the few companies worldwide to produce CdTe thin-film modules. It currently has two manufacturing sites – in Perrysburg (United States) and Kulim (Malaysia) – which, at the end of 2013, had a combined capacity of 2.1 GW. In Q2 2014, the company reported an increase in their average module efficiency to 14 % and a new record for cell at 21 %.

In 2013, the company produced 1.63 GW; for the last quarter of that year it reported production costs of USD 0.56/Wp (EUR 0.43/Wp), including underutilisation and upgrading costs of USD 0.02/Wp (EUR 0.015/Wp).

4.2.7 Motech Solar (Taiwan/China)

Motech Solar (http://www.motech.com.tw) is a wholly owned subsidiary of Motech Industries Inc., located in the Tainan Science Industrial Park. The company started its mass production of polycrystalline solar cells at the end of 2000, with an annual production capacity of 3.5 MW. Production increased from 3.5 MW in 2001 to 1 GW in 2011. In 2009, Motech started the construction of a factory in China, which reached its nameplate capacity of 500 MW in 2011. Total production capacity at the end of 2013 was reported as 1.6 GW, and a total shipment of 1.59 GW was also recorded for 2013.

4.2.8 Neo Solar Power Corporation (Taiwan)

Neo Solar Power (http://www.neosolarpower.com/) was founded in 2005 by Powerchip Semiconductor, Taiwan's largest DRAM company, and went public in October 2007. The company manufactures mono- and multicrystalline silicon solar cells. In 2013, it merged with DelSolar to become the largest Taiwanese cell producer. On 31 March 2014, total installed manufacturing capacity was 2.2 GW for silicon solar cells and 240 MW for modules. The company has plans to double the module manufacturing capacity by the end of 2014 and to increase cell manufacturing capacity to 3 GW by the end of 2015. For 2013, the company reported shipments of 1.4 GW solar cells and 130 MW modules.

4.2.9 Hanwha (China/Germany/Malaysia/ South Korea)

The Hanwha Group (http://www.hanwha.com) acquired a 49.99 % share in Solarfun Power Holdings in 2010 and the name was changed to Hanwha SolarOne in January 2011. It produces silicon ingots, wafers, solar cells and solar modules. The first production line was completed at the end of 2004 and commercial production started in November 2005. The company went public in December 2006 and reported the completion of its production capacity expansion to 360 MW in the second quarter of 2008.

In August 2012, it acquired Q CELLS (Germany/Malaysia), which had filed for insolvency in April 2012. Hanwha, with its two brands Hanwha Q CELLS and Hanwha SolarOne, has a combined production capacity of 2.4 GW of solar cells (1.3 GW in China, 900 MW in Malaysia and 200 MW in Germany). In addition, Hanwha SolarOne has 800 MW of ingot and wafer production capacity. For 2013, Hanwha SolarOne reported shipments of 1.3 GW of PV modules.

4.2.10 Gintech Energy Corporation (Taiwan)

Gintech (http://www.gintech.com.tw/) was established in August 2005 and went public in December

2006. Production at Factory Site A, Hsinchu Science Park, began in 2007 with an initial production capacity of 260 MW and increased to 1170 MW at the end of 2011. The company expanded its capacity to 1.5 GW in 2012. In 2013, shipments were reported at 1.3 GW [Ikk 2014].

4.2.11 Kyocera Corporation (Japan, Czech Republic, Mexico)

In 1975, Kyocera (http://global.kyocera.com/prdct/solar/) started with research into solar cells. The Shiga Yohkaichi factory was established in 1980, and R&D and manufacturing of solar cells and products started with the mass production of multicrystalline silicon solar cells in 1982. In 1993, it became the first Japanese company to sell home PV generation systems.

Besides solar-cell manufacturing plants in Japan, Kyocera has module manufacturing plants in China (joint venture with the Tianjin Yiqing Group [10 % share] in Tianjin since 2003), Tijuana in Mexico (since 2004) and in Kadaň in the Czech Republic (since 2005).

The company is also marketing systems that both generate electricity through solar cells and exploit heat from the sun for other purposes, such as heating water. The Sakura factory, Chiba Prefecture, is involved in everything from R&D and system planning to construction and servicing, and the Shiga factory in the Shiga Prefecture, is active in R&D as well as the manufacturing of solar cells, modules, equipment parts, and devices which exploit heat.

In 2013, Kyocera produced 1.2 GW [Ikk 2014].

4.2.12 Hareon Solar Technology Co. Ltd. (China)

Hareon Solar (http://www.hareonsolar.com) was set up as the Jiangyin Hareon Technology Co. Ltd in 2004 and changed its name to the Hareon Solar Technology Co. Ltd. in 2008. It has five manufacturing facilities in both Jiangsu and Anhui province, including Jiangyin Hareon Power Co. Ltd., Altusvia Energy (Taicang) Co. Ltd., Hefei Hareon Solar Technology Co. Ltd., Jiangyin Xinhui Solar Energy Co. Ltd. and Schott Solar Hareon Co. Ltd. Solar-cell production started in 2009, with an initial capacity of 70 MW. According to the company, in 2014, production capacity was more than 1.5 GW for cells and over 1 GW for modules. For 2013, a production of 1.15 GW is reported [Ikk 2014].

4.2.13 SunPower Corporation (USA/Philippines/Malaysia)

SunPower (http://us.sunpowercorp.com/) was founded in 1988 to commercialise proprietary high-efficiency silicon solar-cell technology. It went public in November 2005. The company designs and manufactures high-performance silicon solar cells based on an interdigitated rear-contact design for commercial use. The initial products, introduced in 1992, were high-concentration solar cells with an efficiency of 26 %. SunPower also manufactures solar cells with an efficiency of 22 %, called Pegasus, which is designed for non-concentrating applications.

The company's main R&D activity is conducted in Sunnyvale (California), United States, and has its cell-manufacturing plants in the Philippines and Malaysia. In 2013, SunPower had two cell-manufacturing plants, one in the Philippines with 700 MW capacity and a joint venture (AUOSP) with AU Optronics Corporation (AUO) in Malaysia with over 800 MW. A 350-MW capacity expansion is planned in the Philippines for 2015. The company has three solar module factories in the Philippines, Mexico and France. Modules are also assembled for SunPower by third-party contract manufacturers in China and California. Total cell production in 2013 was reported at 1.13 GW [Ikk 2014].

4.2.14 Changzhou EGing Photovoltaic Technology Co. Ltd. (China)

EGing PV (http://www.egingpv.com/) was founded in 2003 and operates along the complete PV industry value chain, from the production of monocrystalline furnaces, quartz crucibles, 5-8 inch monocrystalline silicon ingots, supporting equipment for squaring and wire sawing, monocrystalline silicon wafers, solar cells and solar modules. According to the annual report, at the end of 2011, the company had a production capacity of 1 GW across the complete value chain of ingots, wafers, cells and modules with a further increase to at least 1. GW planned. Sales of 1 GW were reported for 2013.

4.2.15 Astronergy Solar (China)

Astronergy Solar (http://www.astronergy.com) was established as a member of the Chint Group in October 2006. The first production line of 25 MW, for crystalline silicon cells and modules, was installed in May 2007 and an increase in production capacity to 100 MW was completed in July 2008. Commercial production of Micromorph® solar modules started in July 2009. The thin-film capacity was 30 MW in 2010, rising to 75 MW in early 2011. At the end of 2013, it acquired Conergy's Frankfurt Oder PV module factory and reopened it with a capacity of 300 MW in August 2014. Total module production capacity is now 1.3 GW and cell production capacity is around 1 GW. For 2013, a production of about 1 GW has been estimated.

4.2.16 Solar Frontier (Japan)

Solar Frontier (http://www.solar-frontier.com/eng/) is a 100 % subsidiary of Showa Shell Sekiyu KK. In

1986, Showa Shell Sekiyu started to import small modules for traffic signals, and began module production in Japan, cooperatively with Siemens (now Solar World). The company developed CIS solar cells and, in October 2006, completed the construction of its first factory with 20 MW capacity in the Miyazaki Prefecture. Commercial production started in the 2007 financial year. The second Miyazaki factory (MP2), with a production capacity of 60 MW, began manufacturing in 2009. In July 2008, the company announced it would open a research centre "to strengthen research on CIS solar-powered cell technology, and to start collaborative research on mass production technology of the solar modules with Ulvac Inc." The aim of this project was to start a new plant in 2011 with a capacity of 900 MW. The ramp-up started in February 2011 and at the end of that year overall capacity was 980 MW. In 2011, the company changed its name to Solar Frontier, and production was reported at 450 MW [Rts 2012]. For 2012, a moderate increase was estimated to over 500 MW. In early 2013, the company reported that the Kunitomi plant (MP3) was operating at full capacity. Production at MP2 was halted at the end of 2012 to make adjustments for the production of new differentiated products. The plant resumed production in July 2013, and in January 2014 the company announced it would build a new factory with a capacity of 150 MW in Ohiramura, Miyagi prefecture. The new plant is scheduled to start operations in March 2015. A production of 930 MW was reported for 2013 [Ikk 2014].

4.2.17 Renewable Energy Corporation AS (Norway/Singapore)

The vision of REC (http://www.recgroup.com/) is to become the most cost-efficient solar-energy company in the world, with a presence throughout the whole value chain. REC is presently pursuing an aggressive strategy to this end. Through its various group companies, it is already involved in all major aspects of the PV value chain. The company is located in Høvik, Norway, and has five business activities, ranging from silicon feedstock to solar-system installations.

In 2011, it decided to close down REC ScanCell, which was located in Narvik and had a production capacity of 180 MW at the end of 2011. The next closures, announced in March and April 2012, were the wafer factory in Glomfjord with a 300 MW capacity for multicrystalline wafers and the 650-MW wafer plant at Herøya. From 2012 onwards, the production of solar cells and modules was restricted to REC Solar Singapore, which operates an integrated production site with a capacity at the end of 2013 of 640 MW for wafers, 770 MW for solar cells and 910 MW for modules. In 2013, module production was reported at 820 MW.

4.2.18 CSUN (China/Turkey)

In 2004, CSUN (http://www.csun-solar.com) was established as CEEG Nanjing PV-Tech Co. (NJPV), a joint venture between the Chinese Electrical Equipment Group in Jiangsu and the Australian Photovoltaic Research Centre . CSUN went public in May 2007, and in May 2013, inaugurated its cell (100 MW) and module (300 MW) manufacturing plant in Turkey. At the end of 2013, the company had a cell capacity of 570 MW and a module capacity of 1.1 GW. For 2013, shipments of about 570 MW have been reported.

4.2.19 Sharp Corporation (Japan)

Sharp (www.sharp-world.com) started to develop solar cells in 1959 and commercial production got under way in 1963. Since its products were mounted on 'Ume', Japan's first artificial satellite for commercial use, in 1974, Sharp has been the only Japanese manufacturer to produce silicon solar cells for use in space. Another milestone was achieved in 1980 with the release of electronic calculators, equipped with single-crystal solar cells.

In 2012, Sharp had a production capacity of 1070 MWp/year (750 MW crystalline silicone and 320 thin film) [Ikk 2014] in Japan, and a thin-film joint venture (3Sun) together with ENEL Green Power and STMicroelectronics in Catania, Italy, with an initial capacity of 160 MW. In 2014, Sharp reached an agreement with ENEL to take over its shares in the 3Sun joint venture, which has a capacity of about 200 MW in 2014. At the end of 2014, a capacity of only 200 MW c-Si in Osaka and 160 MW of thin films will remain. The module plant in Wrexham, UK, had already been closed in February 2014 followed by the closure of the plant in Tennessee, USA in March 2014.

Instead of own manufacturing activities, Sharp has moved to OEM manufacturing, mainly in China and Taiwan, and PV project business. Various sources reported about 700 MW of own cell/thin-film production and 1.8 GW of Sharp branded module shipments in 2013.

4.2.20 ReneSola Ltd. (China)

ReneSola (http://www.renesola.com) was established in 2005 and went public on the New York Stock Exchange in 2008. The company produces polysilicon wafers, solar cells and solar modules. According to ReneSola, at the end of 2013 it had a production capacity of 6000 metric tonnes of polysilicon, 2 GW of wafers, 1.2 GW of modules and 240 MW of solar cells. In addition, the company reported an OEM manufacturing capacity of 1 GW in seven countries: Poland (265 MW), India (240 MW), Malaysia (180 MW), Turkey (120 MW), Japan (80 MW), South Africa (78 MW) and Korea (60 MW). Shipments for 2013 were reported as 1.5 GW for wafers and 1.65 GW for modules.

4.3 Polysilicon supply

Since 2000, the rapid growth of the PV industry led to a situation where, between 2004 and early 2008, the demand for polysilicon outstripped the supply from the semiconductor industry. Prices for purified silicon started to rise sharply in 2007, and in 2008 prices for polysilicon peaked at around USD 500/kg, resulting in higher prices for PV modules. This extreme price hike triggered a massive capacity expansion, not only among established companies, but many new entrants as well. The top 10 silicon manufacturers produced about two-thirds of the total 2011 production. More than 50 companies, mainly in China and Korea, stopped or closed down their production during 2011 and 2012. Nevertheless, the first half of 2013 was characterised by low utilisation rates despite greater solar silicon demand. Thus it can be concluded that available silicon stocks were reduced considerably.

The massive production expansions, as well as the difficult economic situation, led to a fall in prices throughout 2009, reaching about USD 50-55/kg at the end of 2009. There was a slight upwards trend throughout 2010 and early 2011 before prices dropped significantly. In 2013, they started to stabilise and a slight upward trend was observed in 2014. In October 2014, prices were in the USD 25/kg (EUR 19/kg) range for contracted silicon and USD 20/kg (EUR 15/kg) on the spot market.

Projected silicon production capacities for 2014 vary between 310 000 tonnes [Blo 2014a] and 429 860 tonnes [Ikk 2014]. It is estimated that about 27 000 to 30 000 tonnes will be used by the electronics industry. In addition, possible solar cell production will depend on the material used per Wp. The current average worldwide is about 4.8 g/Wp for mono- and 5.5 g/Wp for multicrystalline silicon solar cells.

In January 2011, the Chinese Ministry of Industry and Information Technology tightened the rules for polysilicon factories. New factories must be able to produce more than 3000 metric tonnes of polysilicon a year and meet certain efficiency, environmental and financing standards. The total energy consumption must be less than 200 kWh/kg as China is aiming for large companies with at least an annual capacity of 50 000 tonnes by 2015.

4.3.1 Silicon production processes

The high growth rates of the PV industry and market dynamics forced the high-purity silicon companies to explore process improvements, mainly for two chemical vapour deposition (CVD) approaches – an established production approach known as the Siemens process and a manufacturing system based on fluidised bed (FB) reactors. It is very probable that improved versions of these two types of processes become the workhorses of the polysilicon production industry in the near future.

Siemens process: The Siemens reactor was developed in the late 1950s and has remained the dominant production route ever since. In 2009, about 80 % of total polysilicon manufactured worldwide was made using a Siemens-type process. It involves deposition of silicon from a mixture of purified silane or trichlorosilane gas, with an excess of hydrogen, on to high-purity polysilicon filaments. The silicon growth then takes place inside an insulated reaction chamber or 'bell jar' which contains the gases. The filaments are assembled as electric circuits in series and are heated to the vapour deposition temperature by an external direct current. The silicon filaments are heated to very high temperatures between 1100 and 1175 °C at which trichlorosilane, with the help of the hydrogen, decomposes to elemental silicon and deposits as a thin-layer film on to the filaments. Hydrogen chloride is formed as a by-product.

Temperature control is the most critical process parameter. The temperature of the gas and filaments must be high enough for the silicon from the gas to deposit on to the solid surface of the filament, but well below the melting point of 1414 °C, so that the filaments do not start to melt. Secondly, the deposition rate must be well controlled and not too fast, otherwise the silicon will not deposit in a uniform, polycrystalline manner, making the material unsuitable for semiconductor and solar applications.

Fluidised bed process: A number of companies develop polysilicon production processes based on fluidised bed (FB) reactors. The motivation for using the FB approach is the potentially lower energy consumption and continuous production, compared to the Siemens batch process. In this process, tetrahydrosilane or trichlorosilane and hydrogen gases are continuously introduced into the bottom of the FB reactor at moderately elevated temperatures and pressures. At a continuous rate, high-purity silicon seeds are inserted from the top and suspended by the upward flow of gases. At the operating temperature of 750 °C, the silane gas is reduced to elemental silicon and deposits on the surface of the silicon seeds. The growing seed crystals fall to the bottom of the reactor where they are removed continuously.

MEMC Electronic Materials, a silicon-wafer manufacturer, has been producing granular silicon from silane feedstock using a fluidised bed approach for over a decade. Several new facilities will also feature variations of the FB. Some of the major players in the polysilicon industry, including Wacker Chemie and Hemlock, are developing FB processes while, at the same time, continuing to produce silicon using the Siemens process, too.

Upgraded metallurgical grade (UMG) silicon was seen as one option for producing cheaper solar-grade silicon with 5- or 6-nines purity, but support for this technology is waning in an environment where higher-purity methods are cost-competitive. A number of companies have delayed or suspended their UMG-silicon operations as a result of low prices and lack of demand for UMG materials for solar cells.

4.4 Polysilicon manufacturers

On a global scale, more than 100 companies already produce or have started up polysilicon production. The following list gives a short description of the 10 largest companies in terms of production in 2013. More information about other polysilicon companies can be found in various market studies.

4.4.1 GCL-Poly Energy Holdings Ltd. (China)

GCL-Poly (http://www.gcl-poly.com.hk) was founded in March 2006 and started the construction of its Xuzhou polysilicon plant (Jiangsu Zhongneng Polysilicon Technology Development Co. Ltd.) in July 2006. Phase I had a designated annual production capacity of 1500 tonnes and the first shipments were made in October 2007. Full capacity was reached in March 2008. At the end of 2011, polysilicon production capacity had reached 65 000 tonnes and 8 GW of wafers. The wafer capacity was further increased to 10 GW at the end of 2013. The company reported production of 50 440 tonnes of polysilicon plus sales of 16 329 tonnes of polysilicon and 9.3 GW of wafers for 2013.

The company also invested in the downstream solar business. GCL Solar System Ltd. (SSL) is a wholly owned subsidiary of GCL-Poly Energy Holdings Ltd. and provides solar-system turnkey solutions for residential, governmental, commercial and solar farm projects, including design, equipment supply, installation and financial services. Another subsidiary is GCL Solar Power Co. Ltd. which is developing, operating and managing solar farms.

4.4.2 Wacker Polysilicon (Germany)

Wacker Polysilicon AG (http://www.wacker.com) is one of the world's leading manufacturers of hyper-pure polysilicon for the semiconductor and PV industry, chlorosilanes and fumed silica. In 2011, Wacker increased its capacity to over 40 000 tonnes and reported sales of 32 000 tonnes. The 15 000-tonne factory in Nünchritz, Germany, started production in 2011. In 2010, the company decided to build a polysilicon plant in Tennessee, United States, with a 15 000-tonne capacity. Construction of the new 18 000-tonne factory began in April 2011 and should have been finished at the end of 2013. In addition, in 2012 the company expanded the capacity of its factory in Burghausen by 5000 tonnes, and together with a further expansion of the Nünchritz factory by 5000 tonnes, it plans to have 70 000 tonnes of production capacity in 2014. In 2013, total polysilicon production capacity was 52 000 tonnes and the company reported sales of more than 49 000 tonnes.

4.4.3 Hemlock Semiconductor Corporation (USA)

Hemlock Semiconductor Corporation (http://www.hscpoly.com) is based in Hemlock, Michigan. The corporation was set up as a joint venture between Dow Corning Corporation (63.25 %) and two Japanese firms, Shin-Etsu Handotai Co. Ltd. (24.5 %) and Mitsubishi Materials Corporation (12.25 %). In 2013, Dow Corning Corporation bought the Mitsubishi Materials Corporation share, increasing its own share to 75.5 %.

In 2007, the company had an annual production capacity of 10 000 tonnes of polycrystalline silicon, and production at the expanded Hemlock site (19 000 tonnes) started in June 2008. A further expansion at the Hemlock site, as well as a new factory in Clarksville (Tennessee) United States, began in 2009. Total production capacity was expanded to 56 000 tonnes in 2012, and a production of 33 000 tonnes has been estimated for 2013.

4.4.4 OCI Company (South Korea)

OCI Company Ltd. (formerly DC Chemical) (http://www.oci.co.kr/) is a global chemical company with a product portfolio spanning inorganic chemicals, petro and coal chemicals, fine chemicals, and renewable energy materials. In 2006, the company started its polysilicon business and successfully completed its 6500-tonne P1 plant in December 2007. The 10 500 tonne P2 expansion was completed in July 2009, and with another 10 000 tonnes P3 brought the total capacity to 27 000 tonnes at the end of 2010. The de-bottlenecking of P3 took place in 2011, and increased the capacity to 42 000 tonnes at the end of that year. Further capacity expansions, P4 (20 000 tonnes) and P5 (24 000 tonnes), have been put on hold due to the rapid decline in the price of polysilicon. Instead, the company is pursuing a further de-bottlenecking of the existing plants to increase capacity by 10 000 tonnes by 2015. For 2013, a production of 26 000 tonnes has been estimated from the financial figures published.

OCI invested in downstream business and holds 89.1 % of OCI Solar Power, which develops, owns and operates solar power plants in North America. On 23 July 2012, the company signed a PPA with CSP Energy, Texas, for a 400-MW solar farm in San Antonio (Texas), United States. The solar farm should be operational by 2016.

4.4.5 REC Silicon ASA (Norway/USA)

REC Silicon (http://www.recsilicon.com) is headquartered in Moses Lake, Washington, USA, and has production facilities in Moses Lake and Butte, Montana. The company resulted from the 2013 split of Renewable Energy Corporation into two companies: REC Solar ASA and REC Silicon ASA. In 2005, the Renewable Energy Corporation took over Komatsu's US subsidiary Advanced Silicon Materials LLC (ASiMI), and announced the formation of its silicon division business area, REC Silicon Division, comprising the operations of REC ASiMI and REC Solar Grade Silicon LLC (SGS). At the beginning of 2014, the company announced the formation of a joint venture with Shaanxi Non-Ferrous Tian Hong New Energy Co. Ltd. in China. This joint venture includes the development of an 18 000-tonne fluidised bed reactor (FBR-B) production facility.

Production capacity at the end of 2013 was more than 20 00 tonnes and, according to the company, a total of 19 764 tonnes of polysilicon, of which 16 145 tonnes were FBR, 1758 tonnes of Siemens solar grade and 1961 semiconductor-grade silicon, were produced in 2013.

4.4.6 SunEdison Inc. (USA)

SunEdison (http://sunedisonsilicon.com), formerly MEMC Electronic Materials Inc., has its headquarters in St Peters (Missouri), USA. It started operations in 1959 producing semiconductor-grade wafers, granular polysilicon, ultra-high-purity silane, trichlorosilane, silicon tetraflouride and sodium aluminium tetraflouride. In February 2011, the company and Samsung entered into a 50/50 equity joint venture to build a polysilicon plant in Korea with an initial capacity of 10 000 tonnes in 2013. At the end of 2011, the company closed its 6000-tonne factory in Merano, Italy, and in 2012 it reduced its capacity in Portland (Oregon), USA. The production capacity at the end of 2013 should have been of the order of 12 000 tonnes, although a production of about 11 000 tonnes has been estimated.

SunEdison is developing solar power projects as well as providing solar energy. At the end of 2013, the company had 504 MW under construction and 3.4 GW of projects in the pipeline.

4.4.7 Tokuyama Corporation (Japan)

Tokuyama (http://www.tokuyama.co.jp/) is a chemical firm involved in the manufacturing of solar-grade silicon, the base material for solar cells. According to the company, it had an annual production capacity of 5200 tonnes in 2008 and expanded this to 9200 tonnes in 2010. In February 2011, the company began building a new 20 000-tonne facility in Malaysia. The first phase for 6200 tonnes started a trial production in March 2013 and the second phase for 13 800 tonnes should be fully operational in 2015. A production capacity of 17 200 tonnes was reported for the end of 2013 [Ikk 2014]. A production of 6 000 tonnes is estimated for 2013.

4.4.8 M.Setek Co. Ltd. (Japan)

M.Setek (http://msetek.com) is a subsidiary of Taiwan's AU Optronics and manufactures semiconductor equipment and monocrystalline silicon wafers. It has two plants in Japan (Sendai and Kouchi) and two in the China, Hebei Langfang Songgong Semiconductor Co. Ltd. (Beijing) and Hebei Ningjin Songgong Semiconductor Co. Ltd. (Ningjin). In April 2007, polysilicon production started at the Soma Factory in Fukushima Prefecture. A production capacity of 7 000 tonnes was reported for 2013 and production was estimated to be around 5000 tonnes.

4.4.9 TBEA Silicon Co. Ltd. (China)

TBEA Silicon Co. Ltd. (http://www.tbea.com.cn/) was established at the State Hi-Tech Development Zone in Urumqi, Xinjiang, China by Tebian Electric Apparatus Stock Co. Ltd. and East Electric EMei Semiconductor Institute. At the end of 2013, the company reported a production capacity exceeding 12 000 tonnes, while a production of around 4000 tonnes has been estimated for 2013.

4.4.10 Daqo New Energy Co. Ltd. (China)

Daqo New Energy (http://www.dqsolar.com/) is a subsidiary of the Daqo Group and was founded by Mega Stand International Ltd. in January 2008. Initially, the company built a high-purity polysilicon factory in Wanzhou, China, with an annual output of 3300 tonnes in the first phase. The first polysilicon production line, with an annual output of 1500 tonnes, started operating in July 2008. Production capacity in 2009 was 3300 tonnes and had reached more than 4300 tonnes by the end of 2011. According to the company, production capacity at the end of 2013 was 6150 tonnes and an expansion of the capacity to 12 150 is under way. In 2013, the company reported a polysilicon production of 4293 tonnes.

5 OUTLOOK

After a decade of continued increases in new investments in clean energy worldwide, between 2002 and 2011, 2013 was the second year in which there was a decline in new renewable energy technologies. However, the drop in renewable energy system prices, especially solar photovoltaics, almost compensated for this and allowed these investments to be used for installing a capacity of 87 GW of new clean energy generation, just 1 GW less than in 2012, bringing the total to 735 GW and thus capable of producing more than 1700 TWh of electricity or 70 % of the electricity generated by nuclear power plants worldwide.

For the fourth year in a row, solar power attracted the largest amount of new investments in renewable energies in 2013. Despite a 23 % decline in solar-energy investments, it attracted 52 % of all new renewable energy investments or USD 97.6 billion (EUR 72.3 billion) [Pew 2014]. It is worth mentioning that despite this 23 % decline in solar-energy investments, the annual installed photovoltaic solar-energy capacity actually increased by about 23 % to 39.5 GW.

In 2013, clean energy markets outside the Group of 20 (G20) continued to grow and added about 15 % to exceed USD 27 billion (EUR 20 billion), whereas investments in the G20 countries fell again by 16 % to USD 187 billion (EUR 138.5 billion).

In contrast to Europe and the Americas, where new investments in renewable energy declined by 42 % and 8 % respectively, new investments continued to increase in Asia/Oceania [Pew 2014]. The top country for new renewable energy investment was China with USD 54.2 billion (EUR 40.2 billion), followed by the USA at USD 36.7 billion (EUR 27.2 billion) and Japan with USD 28.6 billion (EUR 21.2 billion).

The European Union as a whole saw investments of USD 34 billion (EUR 25.2 billion), mainly in the United Kingdom (EUR 9.2 billion), the only European market with higher investments, and Germany (EUR 7.5 billion). Japan recorded the biggest change in 2013 with an 80 % increase compared to 2012. Looking at the five-year growth, South Africa is leading with 96 %, followed by Japan (57 %) and Australia (32 %), whereas the European Union saw a decline of 6 %. According to the current market trends, as well as the IEA's Medium-Term Renewable Energy Market Report 2014, this development will continue if no new policies are introduced in Europe [IEA 2014].

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 Japan. Amongst the 20 biggest cell/thin-film PV manufacturers in 2013, only one still had production facilities in Europe, namely Hanwha Q CELLS (South Korea, Germany, Malaysia and China). If Europe wants to regain a double digit market share of the manufacturing industry, a major industry policy effort is needed to revitalise the European PV manufacturing industry. Europe still has an excellent PV R&D infrastructure along the value chain, but it will only be possible to maintain this in the long run if industry players along this value chain, including PV manufacturing, are operating in Europe.

The focus of this report is on solar cells and modules, with some additional information about the supply of polysilicon. Therefore, it is important to remember that the PV industry consists of more than that, and simply looking at cell production does not give the whole picture of the complete PV value chain. Besides the information here about the manufacturing of solar cells, the whole upstream industry (e.g. materials, polysilicon production, equipment manufacturing) and downstream industry (e.g. inverters, BOS components, system development, installations) must also be examined.

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 about 40 GW in 2013. This corresponds to a CAGR of a little more than 34 % over the last 24 years. In 2013, statistically documented cumulative installations worldwide accounted for almost 140 GW. However, the interesting fact is that cumulative production amounts to more than 160 GW over the same period. Assuming that the output of about one to two months of production might be in warehouses or transport, this still leaves a considerable capacity unaccounted for. Some of this unaccounted capacity may be in consumer applications, which do not contribute significantly to power generation, but the vast majority of it is probably being used in stand-alone applications for communication purposes, cathodic protection, water pumping, street lights, and traffic and garden lights, etc.

The temporary shortage in silicon feedstock, triggered by the PV industry's high growth rates over recent years, resulted in the market entrance of new companies and technologies. New production plants for polysilicon, advanced silicon-wafer production technologies, thin-film solar modules and technologies, such as concentrator concepts, were introduced into the market much faster than was expected a few years ago. However, the dramatic price decline for polysilicon and solar modules, triggered by the overcapacity of solar modules and polysilicon, has put enormous economic pressure on a large number of companies and is forcing the consolidation of the industry. The benchmark was set by the Chinese Ministry of Industry and Information Technology when in February 2012 it announced that it was aiming for an industrial consolidation of those companies with a polysilicon production capacity of at least 50 000 tonnes, and solar-cell manufacturers with at least a 5-GW production capacity by 2015 [MII 2012].

Companies with limited financial resources and restricted access to capital are particularly struggling in the current market environment. The existing overcapacity in the polysilicon, solar-cell and module manufacturing industry is expected to continue at least until 2015, when the global PV market should exceed 50 GW per annum. The anticipated growth of annual installations is based on the rapid growth of new markets outside Europe, especially in China, Japan and the USA, but with increasing contributions from emerging markets as well.

Despite the ongoing economic difficulties and political uncertainties, the number and volume of new PV markets worldwide is increasing. In addition, there is a growing number of large investors who are steadily increasing their investments in renewable energy and solar photovoltaics, like Warren Buffet, or even de-investing in fossil energy companies and shifting this investment to renewable energy, as announced by the Rockefeller Brother Fund before the UN Climate Summit 2014 [BBC 2014]. 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 photovoltaics 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. Increasing demand for energy is pushing the prices of fossil energy resources higher. Already in 2007, a number of analysts were predicting that oil prices could hit USD 100/bbl by the end of that year or early in 2008 [IHT 2007]. After the spike in oil prices in July 2008, when they were close to USD 150/bbl, prices fell due to the global financial crisis, reaching a low around USD 37/bbl in December 2008. Since then, the oil price has rebounded, with the IEA reporting average prices for oil imports at around USD 110/bbl between the second quarter of 2011 and the second quarter of 2014, peaking around USD 120/bbl in March and April 2012. Since then, oil prices have fallen below the IEA forecasts of lower-than-expected demand for 2014 and 2015, due to lower-than-expected economic growth worldwide. How and when this trend will change will depend on global economic development, although long-term forecasts are still expecting higher energy prices.

The Energy Watch Group estimated that worldwide spending on combustibles, fuels and electricity was between USD 5500 billion (EUR 4 231 billion) to USD 7500 billion (EUR 5 769 billion) in 2008 [Ewg 2010]. Between 2007 and 2010, about USD 1840 billion (EUR 1 415 billion) were spent on direct fossil fuel consumption subsidies and tax breaks, according to a joint report by the IEA, OPEC, OECD and the World Bank [IEA 2011]. In early 2013, the International Monetary fund published a report on the Energy Subsidy Reform [IMF 2013]. The report states: “Energy subsidies are pervasive and impose substantial fiscal and economic costs in most regions”. On a “pre-tax” basis, subsidies for petroleum products, electricity, natural gas, and coal reached USD 480 billion in 2011 (0.7 % of global GDP or 2 % of total government revenues). The cost of subsidies is especially acute among oil exporters, which account for about two-thirds of the total. On a “post-tax” basis – which also factors in the negative externalities from energy consumption – subsidies are much higher at USD 1.9 trillion (2.5 % of global GDP or 8 % of total government revenues). The advanced economies account for about 40 % of the global post-tax total, while oil exporters account for about one-third.

This is in line with the findings of the 2012 World Energy Outlook, published by the IEA, which states that fossil fuel subsidies accounted for USD 523 billion (EUR 402 billion) or six times more than the total support for renewables in 2011 [IEA 2012].

As early as 2010, the *Financial Times* cited Fatih Birol, 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 is 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."

During the six years between 2007 and 2013, over USD 3400 billion (EUR 2610 billion) were spent on direct fossil fuel subsidies worldwide (this does not include global producer subsidies) [IEA 2011, 2012, 2013]. With 2007 to 2013 PV system prices, this subsidy would have been sufficient to install about 880 GW of PV systems worldwide, able to produce about 1000TWh of electricity or 4.4 % of global electricity demand. With the current residential system costing around USD 1.85/Wp (EUR 1.45/Wp), the amount would be sufficient to install 1840 GW of PV electricity systems.

Following the massive cost reductions for the technical components of PV systems, like modules, inverters, BOS, etc., the next 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 first quarter of 2014, the average system price for residential systems was about EUR 1.64/Wp (USD 2.10/Wp) in Germany, but between USD 2.69 and 3.85/Wp (EUR 2.07 and 2.96/Wp) in California and Japan [Blo 2014a]. According to Bloomberg New Energy Finance (BNEF), one reason for the higher prices in California and Japan is the fact that the higher rate of incentives reduces the need for installers to offer low prices. However, competition and an increasing number of experienced installers are bringing costs down. EPC quotes for large systems are already much lower, and turnkey system prices as low as USD 1.2/Wp (EUR 0.93/Wp) have been reported for projects in India [Blo 2014c].

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. On 9 June 2014, there was about 23 GW of solar power on the German grid, covering more than 50 % of the total electricity demand at noon. To handle these high shares of renewable electricity effectively, 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. In 2012, a business analysis for electric vehicles by McKinsey showed that the then current price of lithium-ion batteries in the range USD 500 to 600/kWh (EUR 385 to 460/kWh) storage capacity could fall to USD 200/kWh (EUR 155/kWh) storage capacity by 2020 [Hen 2012]. This is in line with recent reports published by HSBC and Citygroup in October 2014.

Lithium-ion batteries have an average of 5000 cycles, which corresponds to a net kWh price of USD 0.10 to 0.12/kWh (EUR 0.077 to 0.093/kWh) now and should fall to USD 0.04/kWh (EUR 0.03/kWh) by 2020. However, batteries are only a part of the storage solution. Another important cost factor is the control electronics needed to combine the storage with a PV system and the grid. Currently, this part remains the dominant 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.

With LCOE from PV systems reaching USD 0.09 to 0.14/kWh (EUR 0.069 to 0.108/kWh) in the second quarter of 2014 [Blo 2014c], the additional storage costs already make sense in markets with high peak costs in the evening, where a shift of only a few hours is required. 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 systems are lithium-ion car batteries, which were used before in the BYD 36 taxi for about 4000 cycles [Che 2014].

According to investment analysts and industry prognoses, solar energy will continue to grow at a high rate in the coming years. The different PV industry associations, as well as Greenpeace, the European Renewable Energy Council (EREC) and the International Energy Agency, have developed new scenarios for the future growth of PV systems. Table 6 shows the different scenarios in the Greenpeace/EREC study, the new 2014 IEA PV Technology Roadmap and the 2014 IEA Energy Technology Perspectives scenarios. Older scenarios can be found in the previous PV Status Reports [Jäg 2013]. It is also noteworthy that the 2020 capacity values of the Greenpeace reference scenario (in red) have already been exceeded in 2013. With new installations forecast at between 92 and 108 GW in 2014 and 2015, the high value scenarios are likely to be surpassed [Blo 2014a].

Table 6: Evolution of the cumulative solar electrical capacities until 2050 [Gre 2012, IEA 2014b, c]

Year	2013 [GW]	2015 [GW]	2020 [GW]	2030 [GW]	2035 [GW]
Actual installations	**140**				
Greenpeace[1] (reference scenario)		88	124	234	290
Greenpeace[1] ([r]evolution scenario)		234	674	1 764	2 420
IEA PV Technology Roadmap[2] (hi-Ren Scenario)	135	235	450	1 721	4 674
IEA PV Technology Roadmap[3] (2DS Scenario)	135	180	320	860	2 920
IEA 6DS Scenario 2014[4]		160	250	451	663
IEA 4DS Scenario 2014[4]		180	300	602	1 813
IEA 2DS Scenario 2014[4]		250	450	841	2 835

[1] 2035 values are extrapolated, as only 2030 and 2040 values are given
[2] 2015 and 2020 values are extrapolated, as only 2013, 2030 and 2050 values are given
[3] all values are extrapolated from the % relation between the hi-Ren and the 2DS scenario
[4] 2015 and 2020 values are extrapolated, as only 2030 and 2050 values are given

These projections show that there are huge opportunities for photovoltaics 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 photovoltaics 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.

The IEA's 2014 Energy Technology Perspectives (ETP 2012) state that the total investment costs between 2011 and 2050 for achieving a low-carbon energy sector (2 °C scenario, 2DS) would be an additional UDS_{2012} 44 trillion (EUR 33.8 trillion) compared to the business-as-usual scenario (6DS) with investment needs of UDS_{2012} 118.4 trillion (EUR 91.1 trillion) [IEA 2014b].

However, the estimated fuel savings in the low-carbon scenario are between USD_{2012} 115 trillion (EUR 88.5 trillion) and USD_{2012} 162 trillion (EUR 125 trillion) or 2.9 to 4.1 times the additional investment needed. This clearly indicates the huge societal benefit of a more aggressive climate change approach.

The power sector would require USD_{2012} 39.6 trillion (EUR 30.5 trillion) for the 2DS and USD_{2012} 30.5 trillion (EUR 23.5 trillion) for the 6DS scenario. The additional investments for the 2DS scenario compared to the business as usual would be USD 200 million (EUR 154 million) per year, which is less than the current investment in the renewable energy sector.

Due to the long lifetime of power plants (30 to 50 years), the decisions taken now will influence key socio-economic and ecological factors in our energy system in 2020 and beyond. As mentioned above, the ETP 2014 shows that fuel savings are on average more than three times higher than the additional investment in a low-carbon power supply.

The solar PV scenarios given 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 transforming into a mass-producing industry with its sights on multi-GW production sites. 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 small 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 about 40 % 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 photovoltaics 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 meantime, 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.

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