European Commission

JRC SCIENTIFIC AND POLICY REPORT

PV Status Report 2013

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September 2013

Report EUR 26118 EN

Joint Research Centre

European Commission
Joint Research Centre
Institute for Energy and Transport

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http://iet.jrc.ec.europa.eu/renewable-energies
http://www.jrc.ec.europa.eu/

This publication is a Scientific and Policy Report by the Joint Research Centre of the European Commission.

JRC84082

EUR 26118 EN

ISBN 978-92-79-32719-3 (print)
ISBN 978-92-79-32718-6 (pdf)

ISSN 1831-4155 (print)
ISSN 1977-7086 (online)

doi:10.2790/93873
doi (online):10.2790/93822

Luxembourg: Publications Office of the European Union, 2013

Printed in Belgium

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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 2012, the International Energy Agency (IEA) estimated in its 2012 Energy Technology Perspectives that additional investment requirements in the power sector between 2010 and 2050, compared to the business-as-usual scenario of USD_{2010} 28.4 trillion (EUR 21.8 trillion), would be USD_{2010} 7.6 trillion (EUR 5.8 trillion) for the low-carbon scenario (2°C scenario, 2DS). At first sight, this looks like a lot of additional investment, but it is much less compared to the continuation of fossil fuel subsidies. In 2011, direct consumption subsidies were USD 523 billion (EUR 402 billion) and the support for fossil fuel production added another USD 100 billion (EUR 77 billion). Summing up the figures worldwide over 40 years, this comes to almost USD 25 trillion (EUR 19.2 trillion). Compared to these figures, subsidies for renewable energy were small, quoted as USD 88 billion (EUR 67.7 billion), of which USD 64 billion (EUR 49.4 billion) went on renewable electricity in 2011. It is interesting to note that between 2005 and 2011, the 34 OECD countries supported fossil fuels with around USD 490 billion (EUR 377 billion), of which more than USD 80 billion (EUR 61.5 billion) was spent in 2011 alone. Moreover, the 2DS scenario would have led to fuel savings of around USD_{2010} 34 trillion (EUR 26.2 trillion) over that period.

At the end of 2011, the European Commission presented its Energy Roadmap 2050, and in its Communication on Energy Technologies and Innovation, issued in May 2013, it called for the drafting of an Integrated Roadmap before the end of 2013 and the related Investment Strategy by mid-2014. The discussion about renewable energy targets for 2030 is heating up, and the European Renewable Energy Council (EREC) has already presented its request to set a 45% renewable energy target for the European Union for 2030. It is expected that 70% of new build power capacity between now and 2030 will be renewables.

Photovoltaics 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 the increases, photovoltaics and other renewable energies are the only ones offering a stabilisation or even a reduction in prices in the future.

From 2008 to the second quarter of 2013, residential PV electricity system prices decreased by over 60% in the 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 a 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 2012, solar energy attracted 57.7% of all new renewable energy investments or USD 137.7 billion (EUR 105.9 billion). Investments in small, distributed power capacity, mainly PV energy systems, stood at over USD 72 billion (EUR 55.4 billion).

In 2012, PV industry production increased again but more modestly than previous years, increasing by around 10% and reaching a worldwide production volume of about 38.5 GWp of photovoltaic modules. The compound annual growth rate (CAGR) over the last decade was about 55%, which makes photovoltaics one of the fastest growing industries at present.

The 12th 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 more and more complex. Any additional information would be highly welcome and will be used for the update of the report.

Ispra, August 2013
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INTRODUCTION

Production data for global cell production[1] in 2012 varied between 35 GW 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, while others report sales and again others report production figures. During the first three quarters of 2012, the market outlook for the current year improved considerably and in Asia a strong fourth quarter improved the overall capacity increase.

The data presented, collected from stock market reports of listed companies, market reports and colleagues, were compared to various data sources and thus led to an estimate of 38.5 GW (Fig. 1), representing a moderate increase of about 10% compared to 2011. Another moderate increase is expected for 2013.

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 was observed in Asia, where China and Taiwan together now account for more than 70% of worldwide production.

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 2012, worldwide new investments in clean energy decreased by 11% compared to 2011 to USD 269 billion (EUR 207 billion[2]), which included USD 30.5 billion (EUR 23.5 billion) corporate and government R&D spending [Blo 2013, Pew 2013]. In 2012, clean energy markets outside the Group of 20 (G20) grew by more than 50% to

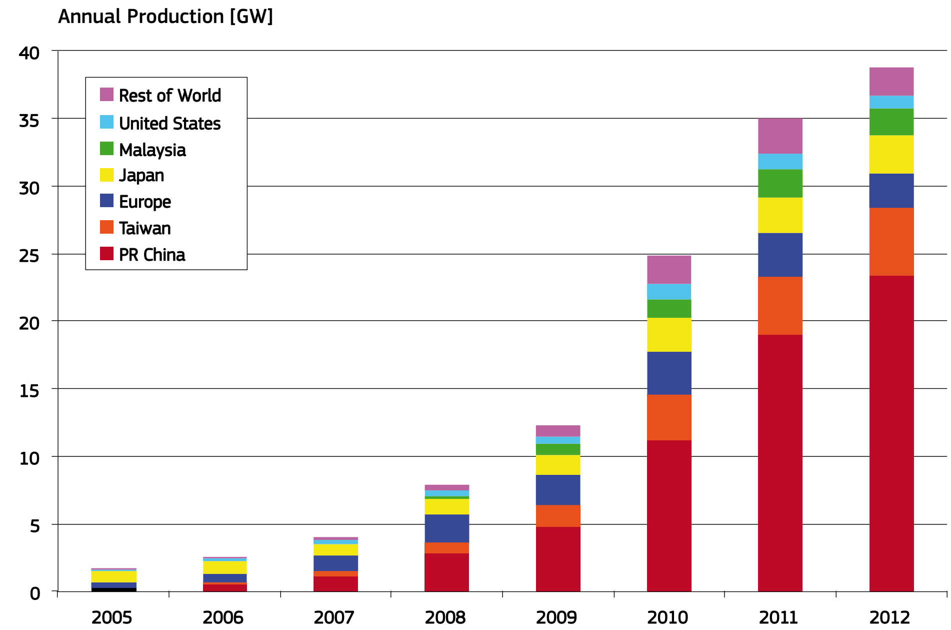


Fig. 1: World PV Cell/ Module Production from 2005 to 2012 (data source: Photon International [Pho 2012], PV Activities in Japan [Pva 2013], PV News [Pvn 2013] and own analysis)

exceed USD 20 billion (EUR 15.4 billion), whereas investments in the G20 countries dropped by 16% to USD 218 billion (EUR 167.7 billion). Despite the overall decline in investments, the decrease in renewable energy system prices

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 1.30

more than compensated for this and allowed these investments to be used for installing a record 88 GW of new clean energy generation capacity, bringing the total to 648 GW and so capable of producing more than 1 500 TWh of electricity or 64 % of the electricity generated by nuclear power plants worldwide.

For the third year in a row, solar power attracted the largest amount of new investments in renewable energies. Despite a 9 % decline in solar energy investments, it attracted 57.7 % of all new renewable energy investments or USD 137.7 billion (EUR 105.9 billion) [Blo 2013a].

In contrast to Europe and the Americas, where new investments in renewable energy decreased, new investments continued to increase in Asia/Oceania and reached USD 101 billion (EUR 77.7 billion) in 2012. Europe took second place with USD 62.1 billion (EUR 47.8 billion), followed by the Americas with USD 50.3 billion (EUR 38.7 billion) [Pew 2013]. China became the largest investor in renewable energy, increasing investments by 20 % to USD 65.1 billion (EUR 50.1 billion), followed by the USA with USD 35.6 billion (EUR 27.4 billion) and Germany with USD 22.8 billion (EUR 17.5 billion). The country with the biggest change in 2012 was South Africa, which moved into ninth place with investments totalling USD 5.5 billion (EUR 4.2 billion).

The existing overcapacity in the solar industry has led to continuous price pressure along the value chain and resulted in a reduction of spot market prices for polysilicon materials, solar wafers and cells, as well as solar modules. Since 2008, PV module prices have decreased by 80 %, and by 20 % in 2012 alone [Blo 2013a]. These rapid price declines are putting all solar companies under enormous pressure and access to fresh capital is key to survival. It is believed that this situation will continue at least until 2015, when the global PV market should exceed 50 GW of new installations. The recent increase in polysilicon spot prices and the levelling of module prices indicate that some production capacity has been taken off and that prices might stabilise for a while until they are back on the learning curve slope. It should be noted that PV system hardware costs are priced more or less the same worldwide, and the so-called ‘soft costs’, which mainly consist of financing and permitting costs, as well as labour requirements and installer/system integrator profits, are the main reason for the significant differences which are still observed.

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

Despite the problems of individual companies, business analysts are confident that the industry fundamentals as a whole will remain strong and that the overall PV sector will continue to experience significant long-term growth. In July 2013, the IEA published its second Medium-Term Renewable Energy Market Report, and raised the predicted increased capacity to 300 GW of cumulative PV installations in 2018 [IEA 2013].

Market predictions for the 2013 PV market vary: 31 GW according to Solarbuzz, 33.8 GW in the Bloomberg conservative scenario, > 35 GW according to IHS research and 39.7 GW in the Bloomberg optimistic scenario [Blo 2013b, IHS 2013, Sol 2013]. For 2014, analysts expect a further increase to > 40 GW, mainly driven by the growing Asian markets. Even in the case of optimistic forecasts, massive overcapacities in cell and module manufacturing will continue to exist. Depending on how the capacities are calculated, in 2013 these range from 60 to 70 GW.

In the past, despite a number of bankruptcies and companies with idling production lines or even permanent closures of their production facilities, the number of new entrants to the field, notably large semiconductor or energy-related companies, have overcompensated for this. The current overcapacity situation is not expected to ease before 2015, when the market volume is expected to exceed 50 GW per year. However, the rapid changes in the sector and the difficult financing situation make a reasonable forecast for future capacity developments very speculative.

The consequence is continued price pressure in an over-supplied market, which will accelerate the consolidation of the PV industry and spur even more mergers and acquisitions.

The existing overcapacity is a result of very ambitious investments dating back to 2010. It was triggered by the more than 150 % growth of the PV market that year, which peaked in equipment spending of about USD 14 billion (EUR 10.8 billion) in 2011. Since then equipment spending has declined dramatically and will probably reach its lowest point at around USD 1 to 2 billion (EUR 0.77 to 1.54 billion) this year before a moderate recovery become possible from 2014 onwards. This development has had a serious effect on equipment manufacturers, which now need a new strategy for the PV industry. Companies with no significant business segments outside the PV supply chain have been hit hardest and some of them are struggling to survive the slump until the predicted recovery kicks in.

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 potential for electricity interruption due to grid overloads in emerging countries, 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 2013 vary between 290 000 tonnes [Blo 2013b] and 409 690 tonnes [Ikk 2013]. It is estimated that about 27 000 tonnes will be used by the electronics industry. The possible solar cell production will, in addition, depend on the material used per Wp. The current worldwide average is about 5.6 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 tracks – 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) and this occurs in a limited geographical range – the 'sun belt' of the Earth. 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 more fierce.

It can be concluded that in order to maintain the extremely high growth rate of the PV industry, different technology pathways have to be pursued at the same time. The cost share of solar modules in a PV system has dropped below 40 % in a residential system and below 50 % in a commercial system, so the soft costs have to be targeted for further significant cost reductions.

With increasing shares of PV electricity in the grid, the economics of integration becomes more and more important 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 costs of electricity generated using PV modules have dropped to less than 0.05 EUR/kWh, but the main cost component relates to getting the electricity from the module to where it is needed. Therefore, new innovative and cost-effective overall electricity system solutions for the integration of PV electricity are needed to realise the vision of **PV as a Major Electricity Source** for everybody everywhere. More is needed to optimise the non-PV costs, and further public support, especially for regulatory measures, is crucial.

2. THE PHOTOVOLTAIC MARKET

After the worldwide PV market more than doubled in 2010, the market grew again by almost 30 % in 2011 and then another 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 connected only in 2011. There is uncertainty about the actual installation figures for China. The Chinese National Energy Administration published a cumulative installed capacity of 7 GW at the end of 2012, whereas most other market reports cite figures of between 8 and 8.5 GW [NEA 2013]. The stronger than expected market in Germany and the strong increase of installations in Asia and the USA resulted in a new installed capacity of about 30 GW in 2012 and for 2013, an increase to about 35 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 2012, of the total worldwide 100 GW of solar PV electricity generation capacity, the European Union had a cumulative installed capacity of over 69 GW, making it the leader in PV installations.

2.1 Asia & Pacific Region

The Asia & Pacific Region continued its upward trend in PV electricity system installations. There are a number of reasons for this development, ranging from declining 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, South Korea, Taiwan, Thailand, the Philippines and Vietnam show a very positive upward trend, thanks to increasing governmental commitment to the promotion of solar energy and the creation of sustainable cities.

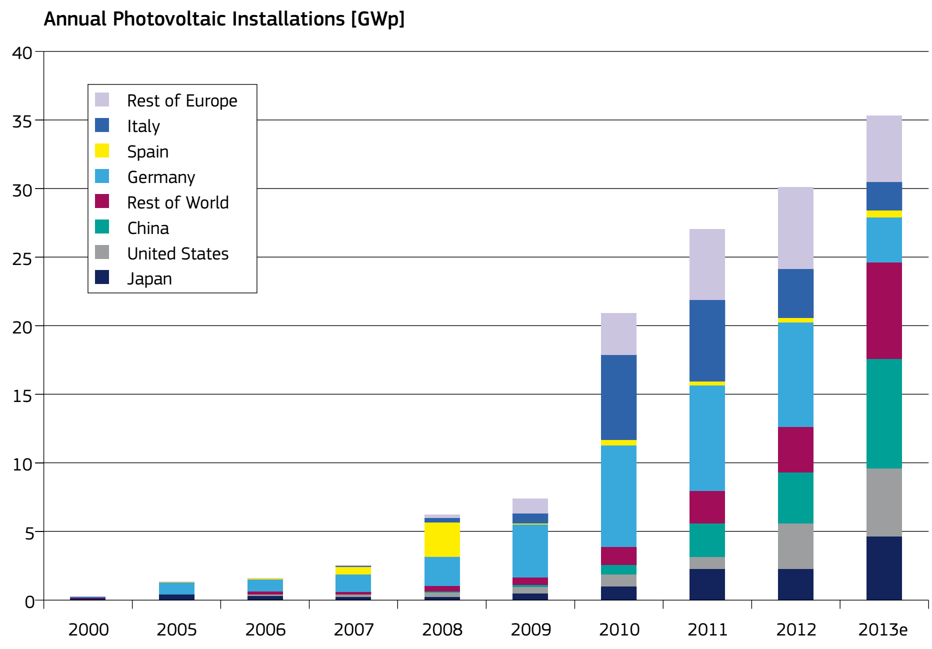
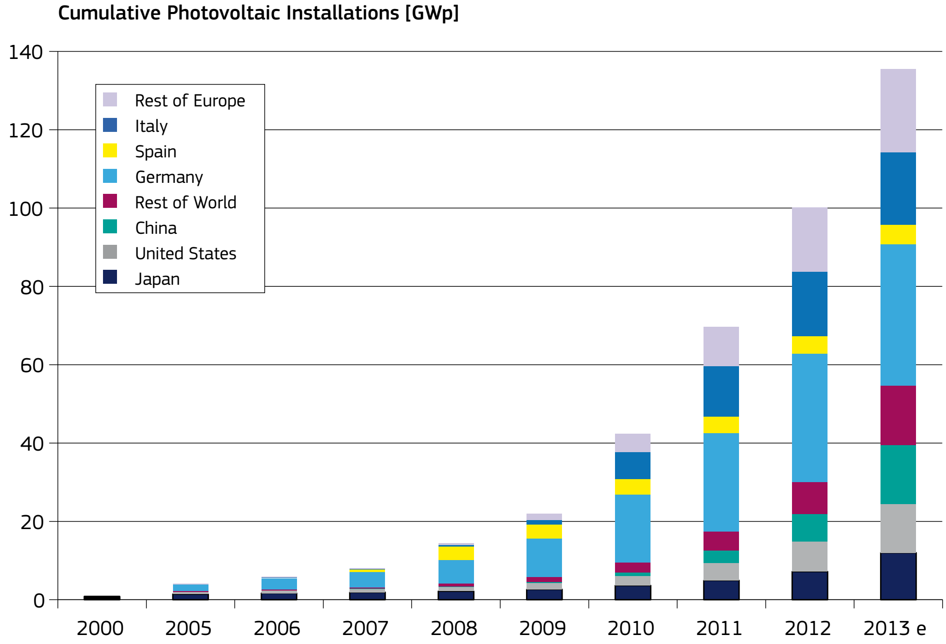


Fig. 2: Annual PV installations from 2000 to 2013 (data source: [Epi 2013, NEA 2013, Sys 2013] and own analysis)

Fig. 3: Cumulative PV installations from 2000 to 2013 (data source: [Epi 2013, NEA 2013, Sys 2013] and own analysis)



The introduction or expansion of feed-in tariffs (FiTs) is expected to be a major additional stimulant for on-grid solar PV system installations for both distributed and centralised solar power plants in countries such as Australia, Japan, Malaysia, Thailand, Taiwan and South Korea.

In 2012, about 8.5 GW of new PV electricity generation systems were installed in the region, which corresponds to a 60 % growth compared to 2011. The largest market was China with 3.7 GW, followed by Japan with 2.3 GW and Australia with over 1 GW. In 2013, a market increase to about 20 GW is expected, driven by the major market growth in China (~ 6 to 8 GW), India (> 1 GW), Japan (6.9 to 9.4 GW), Malaysia and Thailand. The market expectations for 2014 exceed 25 GW.

2.1.1 Australia

In 2012, slightly more than 1 GW of new solar PV electricity systems were installed in Australia, bringing the cumulative installed capacity of grid-connected PV systems to 2.45 GW. In 2011, PV electricity systems accounted for 36 % of all new electricity generation capacity installed. As in 2011, the market in 2012 was dominated by grid-connected residential systems, which accounted for more than 90 % of new PV electricity system capacity of 1 GW. The average PV system price for a grid-connected system fell from 6 AUD/Wp (4.29 EUR/Wp[3]) in 2010 to 3.9 AUD/Wp (3 EUR/Wp[4]) in 2011 and 3.0 AUD/Wp (2.15 EUR/Wp[4]) in early 2013. As a result, the cost of PV-generated electricity has reached or is even below the average residential electricity rate of 0.27 AUD/kWh (0.19 EUR/kWh).

In 2012, PV electricity systems generated 2.37 TWh or about 1 % of Australia's total electricity. The total renewable electricity share was 13.34 % and this should increase to 20 % by 2020. For 2013, the market forecast is 750 MW.

Within two years, Australia has installed almost 2 GW of PV capacity and about 10 % of residential buildings now have a PV system. Initially most installations took advantage of incentives under the Australian Government's Renewable Energy Target (RET) mechanisms and FiTs in some states and territories. At the beginning of 2011, 8 of the 11 Australian federal states and territories had introduced 11 different kinds of FiT schemes, mainly for systems smaller than 10 kWp. All except three of these schemes had built-in caps which were partly reached that year, so that in 2012 only six schemes were available for new installations.

2.1.2 India

For 2012, market estimates for solar PV systems vary between 750 and 1 000 MW, due to the fact that some statistics cite the financial year (FY) and others the calendar year. According to the Ministry of New and Renewable Energy (MNRE), the total capacity at the end of FY 2012/13[5] was 1.9 GW grid-connected and 125 MW off-grid PV capacity. The Indian Jawaharlal Nehru National Solar Mission

3) Average exchange rate for 2010 and 2013: EUR 1 = AUD 1.40

4) Average exchange rate for 2011: EUR 1 = AUD 1.30

5) Financial year ends on 31 March

(JJNSM) was launched in January 2010, and it was hoped that it would give impetus to the grid-connected market. The National Solar Mission 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. After only a few MW were installed in 2010, installations in 2011 slowly picked up, but the majority of the JJNSM projects will come on-line from 2015 onwards. Market expectations for 2013 vary between 1 and 1.35 GW [Bri 2013, Mer 2013].

2.1.3 Israel

A FiT was introduced in Israel in 2008 and four years later the grid-connected PV market saw about 60 MW of newly connected capacity. 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. In August 2012, about 215 MW had been built and a further 300 MW approved [Blo 2012]. The approved FiTs depend on the system size segment and have individual caps. Market expectations for 2013 range between 150 and 200 MW.

2.1.4 Japan

In 2012, the Japanese market experienced significant growth, increasing its domestic shipments to 2.47 GW. Cumulative installed capacity increased by about 1.7 GW to reach 6.6 GW at the end of 2012 [IEA 2013a]. Under a new FiT scheme, introduced in July 2012 [METI 2013], more than 20.9 GW had received approval as of the end of May 2013. The market outlook for Japan is brighter and for 2013 it is between 6.9 and 9.4 GW [Blo 2013c].

A consequence of the accident at the Fukushima Daiichi Nuclear Power Plant in March 2011 was the reshaping of the country's energy strategy. For PV power, an official target of 28 GW was set for 2020. In July 2012, a Ministry for Economy, Trade and Industry (METI) panel proposed the long-awaited plan to reform the country's power market. The aim of the plan is to increase renewable power supply from the 2011 level of 11% to 25% in 2020 to 35% by 2030.

Until 2010, residential rooftop PV systems represented about 95% of the Japanese market. In 2011, due to changes in permitting, large ground-mounted systems as well as large commercial and industrial rooftop systems increased their market share to about 20%.

In June 2012, METI finally issued the Ministerial Ordinances for the new FiTs for renewable energy sources and in March 2013 it adjusted them. Starting on 1 April 2013, the tariff for commercial installations (total generated power) larger than 10 kWp is 36 JPY/kWh for 20 years and for residential installations (surplus power) smaller than 10 kWp it is 38 JPY/kWh for 10 years [Ikk 2013].

2.1.5 People's Republic of China

In 2012, the Chinese PV market grew by 3.7 GW, bringing the cumulative installed capacity to about 7 GW [NEA 2013]. By the end of 2012, about 3.3 GW of this capacity was connected to the grid [Ser 2013]. This represents a 600% increase compared to 2010, but still only 16% of China's total PV production. On 7 January 2013, the National Energy Administration (NEA) announced an ambitious 10 GW target of new PV installations for 2013 [NEA 2013]. A further increase can be expected due to the recent change in the solar energy target for 2015, which was increased to 41 GW[6] by the NEA [Blo 2013]. In a recent presentation, a representative of the Energy Research Institute of the National Development and Reform Commission mentioned that a target of 100 GW of cumulative installed capacity by 2020 is under discussion [Wan 2013].

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 GDP. The total investment in the power sector under the 12th Five-Year Plan is expected to reach USD 803 billion (EUR 618 billion), with USD 416 billion (EUR 320 billion) or 52% 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 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 50000 tonnes 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 0.8 CNY/kWh (0.098 EUR/kWh[7]) by 2015 and 0.06 CNY/kWh (0.074 EUR/kWh) by 2020.

6) PV and Solar Thermal Electricity Generation (STEG)

7) Exchange rate for 2012: EUR 1.0 = CNY 8.1

In August 2012, the NEA released the new renewable energy five-year plan for 2011-2015 [NEA 2012]. The NEA's new goal is for renewable energy to supply 11.4% of the total energy mix by 2015. To achieve this goal, the renewable power generation capacity has to increase to 424 GW. Hydro-power provides the main source, with 290 GW including 30 GW pumped storage, followed by wind with 100 GW, solar with 21 GW (this was then increased to 41 GW) and biomass with 13 GW.

The plan estimates 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 2011-15, namely 61 GW hydro, 70 GW wind, 21 GW solar[8] (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 investment figures necessary are in line with a World Bank report stating that China needs an additional annual investment of USD 64 billion (EUR 49.2 billion) over the next two decades to implement an 'energy-smart' growth strategy [WoB 2010]. However, the report also says that the 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 the 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.

2.1.6 South Korea

In 2012, about 250 MW of new PV systems were installed in South Korea, bringing the cumulative capacity to a total of 981 MW [IEA 2013b]. Since January 2012, Korea's Renewable Portfolio Standard (RPS) has officially replaced the FiTs. For 2013, the RPS set-aside quota was set at 450 W and it should increase to 1.2 GW in 2016. This results in annual targets of 230 MW in 2013, 240 MW in 2014, 250 MW in 2015 and 260 MW in 2016. Under the RPS, income for power generated by renewable energy sources is a combination of the wholesale system marginal electricity price plus the sale of Renewable Energy Certificates (RECs) – certificates in the second half of 2012 were around 40000 KRW/MWh (26-35 EUR/MWh[9]). 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.

The new RPS programme obliges power companies with at least 500 MW of power capacity to increase their renewable energy mix from at least 2% in 2012 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.

2.1.7 Taiwan

In June 2009, the Taiwan Legislative Yuan gave its final approval to 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 be in 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 12502 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).

Between 2009 and 2012 a total capacity of 194 MW was installed, so that by the end of 2012 the total capacity had risen to 222 MW[MoE 2013]. The FiTs in the first half of 2013 for rooftop systems were 8.4 TWD/kWh (0.215 EUR/kWh[10]) for systems up to 10 kW, 7.54 TWD/kWh (0.193 EUR/kWh) for systems between 10 and 100 kW, 7.12 TWD/kWh (0.183 EUR/kWh) for systems between 100 and 500 kW and 6.33 TWD/kWh (0.162 EUR/kWh) for systems larger than 500 kW. Ground-mounted systems had a tariff of 5.98 TWD/kWh (0.153 EUR/kWh). For the second half of 2013, a tariff reduction of 2.5% to 6.1% is foreseen to reflect declining system prices.

The installation targets for 2013 were increased twice and now stand at 175 MW. This is in line with the new Million Solar Rooftop Program, which aims to achieve an installation capacity of

8) Already updated

9) Exchange rate: EUR 1 = KRW 1 420

10) Exchange rate: EUR 1 = TWD 39

610 MW by 2015 and 3.1 GW by 2030. However, the increased installation target for 2013 only represents 3.5% of the total 2012 production volume.

2.1.8 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 final energy consumption of the country 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 8 THB[11]/kWh (0.182 EUR/kWh) Adder (facilities in the three southern provinces and those replacing diesel systems are eligible for an additional 1.5 THB/kWh (0.034 EUR/kWh)) was reduced to 6.5 THB/kWh (0.148 EUR/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, due to original target being 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) approved FiTs for rooftop and community-owned ground-mounted solar plants in addition to the already existing Adder scheme. The final details of how the FiT will be calculated and paid are not yet available.

At the end of 2012, grid-connected PV systems were producing about 360 MW, of which 210 MW were installed in that year [IEA 2013b]. In September 2012, projects with around 1.8 GW capacity had signed PPAs, projects with 76 MW already had Letters of Intent (LOI) and projects offering 925 MW were waiting for the LOI [Kru 2013].

2.1.9 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 April 2013, more than 2 million SHSs had been installed in Bangladesh [WoB 2013]. Current installations rates are more than 60000 units per month.

In 2011, the ADB agreed to provide Bangladesh with financial support for implementing the installation of 500 MW within the framework of the Asian Solar Energy Initiative [Dai 2011, Unb 2011].

Indonesia: The development of renewable energy is regulated in the context of the national energy policy by Presidential Regulation N° 5/2006 [RoI 2006]. The decree states that 11% of the national primary energy mix in 2025 should come from renewable energy sources and the target for solar PV is set at 1000 MW by 2025. At the end of 2011 about 20 MW of solar PV systems were 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]. According to media reports, Indonesia will publish a tender for 150 MW of PV projects in 2013. A new policy to promote solar energy through auction mechanisms was published in June 2013 [Blo 2013e]. It still remains to be seen how this new policy will influence the market.

Kazakhstan: The development of renewable energy is one of the priorities of the State Programme for 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 2011, JSC NAC Kazatomprom and a French consortium headed by Commissariat a l'energie atomique et aux energies alternatives (CEA) jointly began the project Kaz PV, which aims to produce PV modules based on Kazakhstan silicon [Kaz 2011]. The first step 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].

11) Exchange rate EUR 1 = THB 44

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 (KETHHA).

In April 2011, renewable energy FiTs were passed by the Malaysian Parliament with the target of having 1.25 GW installed by 2020. For the period from December 2011 to June 2014, PV has been allocated a total quota of 125 MW. The 2013 tariffs set by the Sustainable Energy Development Authority (SEDA) were between 0.782 and 1.555 MRY/kWh (0.195 to 0.389 EUR/kWh[12]), depending on the type and system size. In addition, there is a small bonus for local module or inverter use. An annual digression of the tariffs is foreseen. As of 30 April 2013, 28.92 MW of PV systems, under the new FiT scheme, are already operational and another 141.58 MW have received approval and are in various stages of project planning or installation [Sed 2013].

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

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 installations to be implemented in the country over the next three years. A FiT of 17.95 PHP/kWh (0.299 EUR/kWh)[13] was suggested, 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 9.68 PHP/kWh (0.183 EUR/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.

SunPower had two cell manufacturing plants outside Manila, but decided to close down Fab. N° 1 early in 2012. Fab. N° 1 had a nameplate capacity of 125 MW and Fab. N° 2 has a nameplate capacity of 575 MW.

Vietnam: In December 2007, the National Energy Development Strategy of Vietnam was approved. It gives priority to 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 the 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 were installed, mainly in off-grid applications.

On 14 May 2011, the Indochinese Energy Company (IC Energy) started preparing the foundations for a thin-film solar panel factory with an initial capacity of 30 MW and a final capacity of 120 MW in the central coastal province of Quang Nam. However, in June 2012 the company applied for permission to delay the project with no new date set.

In January 2013, WorldTech Transfer Investment and the UAE-based Global Sphere broke ground for a solar-panel manufacturing plant in the central province of Thua Thien-Hue [Glo 2013]. The plant is located in the Phong Dien Industrial Park and the first phase of the project (60 MW) should be operational by June 2015. The plan is to increase capacity to 250 MW in a second phase.

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 and especially photovoltaics, as well as the varying grades of liberalisation of domestic electricity markets. Since 2000, solar PV electricity generation capacity has

12) Exchange rate: EUR 1.0 = MRY 4.0

13) Exchange rate for 2011: EUR 1 = PHP 6

14) Exchange rate for 2012: EUR 1 = PHP 53

increased 373 times from 185 MW in 2000 to 69 GW at the end of 2012 (Fig. 4) [Epi 2013, Sys 2013].

A total of about 45 GW of new power capacity were connected in the EU last year and 12.5 GW were decommissioned, resulting in 32.5 GW of new net capacity (Fig. 5) [Ewe 2013, Sys 2013]. PV electricity generation capacity accounted for 16.8 GW, or 51.7% of the new net capacity. In terms of new net capacity, wind power was second with 11.7 GW (36%), followed by 5 GW (15.4%) gas-fired power stations; 1.3 GW (4%) biomass, 0.8 GW (2.5%) solar thermal power plants, 266 MW (0.8%) hydro and 61 MW (0.2%) other sources. The net installation capacity for coal-fired, oil-fired and nuclear power plants was negative, with a decrease of 2.3 GW, 3.2 GW and 1.2 GW respectively. In 2012, the renewable share of new power installations was more than 69% and more than 95% of new net capacity.

The net growth of renewable energy power generation capacity between 2000 and 2012 was 178 GW, compared to 121 GW for new gas-fired capacity and a reduction in coal (-12.7 GW), oil (-17.4) and nuclear (-14.7 GW). Wind (96.7 GW) and PV (69 GW) accounted for more than 93% of the renewable capacity. This net growth of 178 GW to a total of 316 GW of renewable capacity increased the total share of renewable power capacity from 22.5% in 2000 to 33.9% in 2012.

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

2.2.1 Belgium

Belgium showed another strong market performance year in 2012 with new PV system installations of 882 MW, bringing the cumulative installed capacity to 2694 MW. PV power covered 14% of Belgium's residential consumption, or 2.8% of the country's total electricity needs.

However, most of the installations were again in Flanders. Green certificates, issued since 1 January 2006, could initially be claimed for 20 years but the system was suspended at the end of July 2012 and replaced by a new regime for PV systems commissioned after 1 August 2012 [Bel 2012, 2013]. For systems smaller than 250 kWp the tariff was reduced from 0.23 EUR/kWh to 0.21 EUR/kWh and for larger systems from 0.15 EUR/kWh to 0.09 EUR/kWh for systems installed before 2013. At the same time, the period for which the certificates could be claimed was reduced from 20 to 10 years.

As of 1 January 2013 the right to receive green certificates depends on the duration of the amortisation period – for PV it is 15 years in the first half of 2013 and the net metering scheme for systems below 10 kW continued. A technology-dependent banding factor, which is set twice a year by the Flemish Energy Agency (VEA), was introduced so that one certificate is no longer for 1 MWh, but now depends on the type of installation [Res 2013]. Since 1 January 2013 the value of the certificates has been EUR 93.

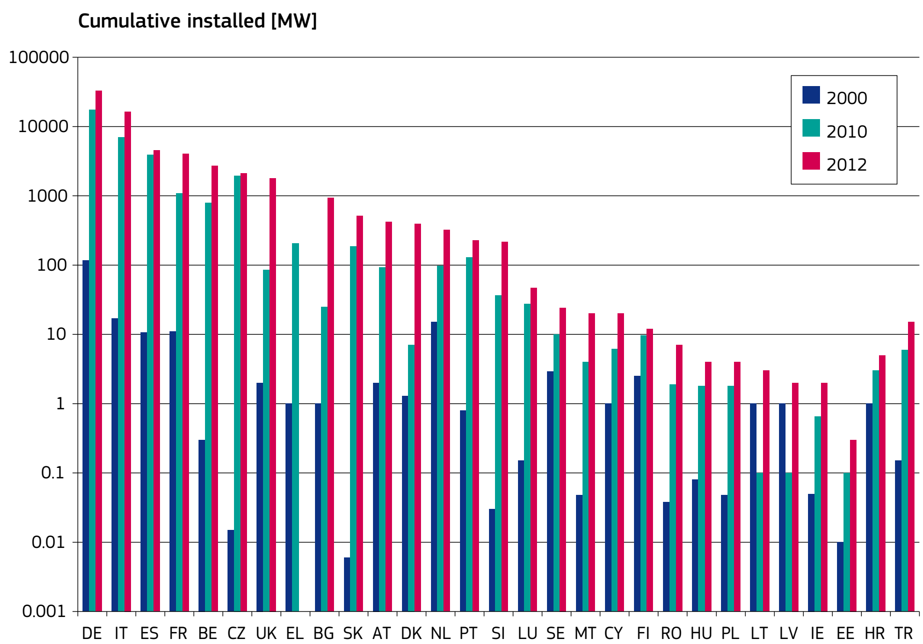
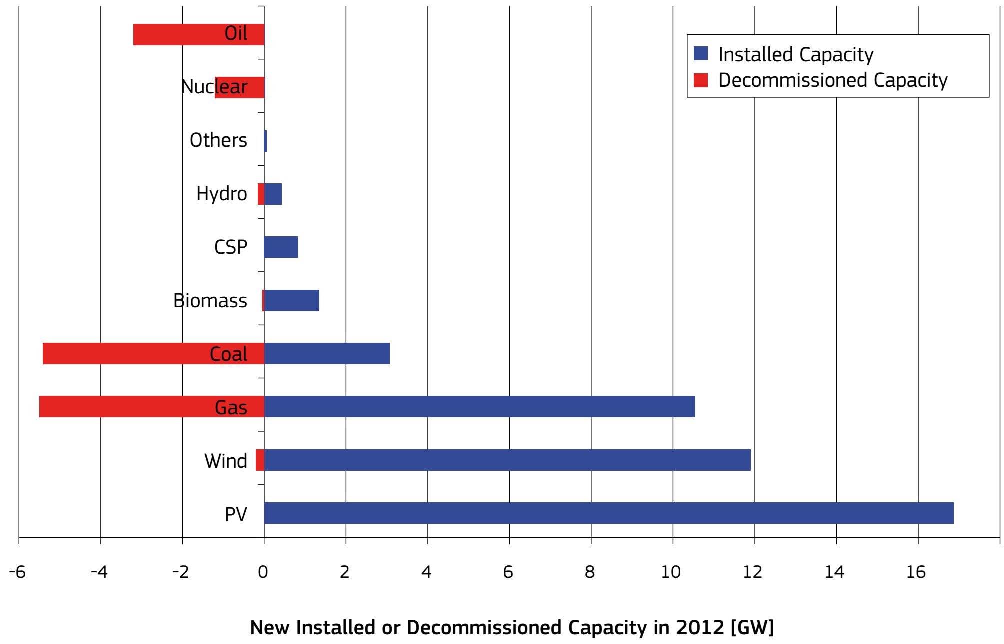


Fig. 4: Cumulative installed grid-connected PV capacity in EU + CC.
Note that the installed capacities do not correlate with solar resources

Fig. 5: New connected or decommissioned electricity generation capacity in the European Union in 2012.



In Wallonia, the green certificate scheme called SOLWATT was replaced by a new scheme called QUALIWATT, which came into effect on 1 April 2013 [GoW 2013]. The main change is that green certificates with a value of 0.065 EUR/kWh are only granted until the PV installation is fully reimbursed and the maximum duration is 10 years. In addition, for systems below 10 kW the net metering continues and a progressive pricing system has been introduced.

The value of green certificates in the Brussels Region is EUR 65 and for PV systems there is a multiplier of 2.2. In addition, for systems below 5 kWp the possibility of net metering exists as long as the generated electricity does not exceed the consumer's own electricity demand.

2.2.2 Bulgaria

In May 2011, a new Renewable Energy Source (RES) Act was approved. The new law fixed the FiT levels and this resulted in new installations of around 110 MW, increasing the total installed capacity to 134 MW at the end of 2011. At the end of 2012, 933 MW of PV systems were cumulatively installed.

In March 2012, the Bulgarian Parliament voted on the revision of the RES Act, which was then published in the State Gazette in April [GoB 2012]. The most significant change is that the price at which electricity will be 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 amounts to 20% of the FiT. For systems commissioned in the first half of 2012, the fee is 39% of the FiT, for systems commissioned between 1 July and 31 August 2012, the fee is 5% and after 1 September 2012, 1% of the respective FiT applies [Sew 2012].

On 1 June 2012, modified FiTs went into force, which corresponded to a 34% to 54% reduction, depending on the system type. In July 2012, SEWRC proposed a further reduction, ranging between 5% and 35%, which went into force in October 2012 [Sew 2012a].

2.2.3 Denmark

The introduction of a net-metering system and high electricity prices of 0.295 EUR/kWh resulted in 378 MW of PV systems being installed in Denmark in 2012. Due to this rapid development, the regime was changed in November 2012 [GoD 2012]. Under the new rules, full net metering is only possible within one hour of the electricity being produced, and in 2013 the excess electricity which is exported to the grid is reimbursed at 1.30 DKK/kWh (0.174 EUR/kWh[15]). To take into account decreasing PV system prices, this rate will decrease to 1.17 DKK/kWh (0.157 EUR/kWh) in 2014 and about 1.00 DKK (0.174 EUR/kWh) in 2015. After 10 years, the rate will be reduced to about 0.60 DKK/kWh (0.080 EUR/kWh).

15) Exchange rate: EUR 1.00 = DKK 7.46

2.2.4 France

In 2012, 1.08 GW of new PV systems were installed in France, so increasing the cumulative installed capacity to over 4 GW, including about 300 MW in the French Overseas Departments. New PV installations in mainland France accounted for 35 % of total new electricity production capacity commissioned in 2012. Of the total capacity, residential systems smaller than 3 kWp represent 16 % or 0.64 GW, systems up to 250 kWp account for 40 % or 1.6 GW and systems larger than 250 kWp add 44 % or 1.76 GW.

At the moment, France has three different support schemes for photovoltaics. For systems up to 100 kWp there is the FiT (allocation of 200 MW for residential and 200 MW for commercial applications), for rooftop systems between 100 and 250 kWp a 'simplified' call for tender with a volume of 120 MW for 2013 and for systems larger than 250 kWp (large rooftop and ground-mounted systems) an additional call for tender with a volume of 400 MW.

In 2012, four tenders were launched and the average electricity sale price proposed by bidders fell from 229 EUR/MWh during the first round to 194 EUR/MWh in the fourth one.

The new FiTs for 2013 were published in February 2013 and it is expected that they will be adjusted every three months [GoF 2013]. PV systems with defined European content are eligible for a bonus of 5 % to 10 %.

2.2.5 Germany

Germany had a slight increase compared to 2011, from 7.5 GW to 7.6 GW [Bun 2013]. The German market growth is directly correlated to the introduction of the Renewable Energy Sources Act or *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 decrease, which was adjusted over time to reflect the rapid growth of the market and corresponding price reductions. 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.

The German market showed strong performance throughout 2012 with peaks of 1.2 GW in March, 1.8 GW in June and 1 GW in September. At the end of 2012, the total installed capacity was 32.7 GW. 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 (July 2013: 0.151 EUR/ kWh) is now below the electricity rate consumers are paying (0.287 EUR/kWh) makes the increase of self-consumption more attractive and is opening up new possibilities for the introduction of local storage [Bun 2013, Une 2013]. Since 1 May 2013 the Kreditanstalt für Wiederaufbau is offering low interest loans with a single repayment bonus of up to 30 % and a maximum of 600 EUR/kW of storage for PV systems up to 30 kWp [KfW 2013]. The maximum repayment bonus is limited to EUR 3 000 per system.

2.2.6 Greece

In 2009, Greece introduced a generous FiT scheme but had a slow start until the market accelerated in 2011 and 2012. In 2012, 687 MW of new PV systems were installed, more than 1.5 times the 439 MW which were cumulatively installed by the end of 2011. By April 2013, the total installed capacity had exceeded 2 GW (over 1.9 GW on mainland Greece and over 115 MW on the islands) [Hen 2013, Lag 2013].

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 as of 1 June 2013.

2.2.7 Italy

Italy connected more than 3.5 GW, increasing cumulative installed capacity to 16.4 GW by the end of 2012 [Gse 2013]. The *Quinto Conto 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 increased from EUR 500 million to EUR 700 million. In addition, a new requirement to register systems larger than 12 kWp was introduced. On 6 June 2013, Gestore Servizi Energetici (GES) announced that the EUR 6.7 billion ceiling of the bill has 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 18.8 TWh or 7.3 % of the total electricity during the first seven months of 2013 [Ter 2013]. The highest monthly coverage was in June, when PV electricity provided 10.6 % of the Italian energy supply.

2.2.8 Slovakia

After two years of rapid growth the Slovakian market decreased by over 90% and only 29 MW were newly installed in 2012. The total capacity of 517 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 is limited to systems up to 30 kW that are placed on buildings.

2.2.9 Spain

Spain is still third in Europe with regard to the total cumulative installed capacity, with 4.2 GW. Most of this capacity was installed in 2008 when the country was the biggest market, with close to 2.7 GW in 2008 [Epi 2013]. 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 1758/2008) 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 no longer free-field systems. These changes resulted in a sharp fall in new installations. In 2012, new system installations with a capacity of 194 MW increased total capacity to 4.5 GW. Electricity generated with PV systems contributed 7.8 TW or 2.9% of the Spanish demand in 2012.

In January 2012, the Spanish Government passed the Royal Decree 1/12 [GoS 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 is that Spain's energy system had until then amassed a EUR 30 billion power-tariff deficit and it is argued that the special regime for renewable energy is the main reason. However, for over a decade the Spanish Government has prevented utilities from charging consumers the true costs 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 enabled 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 they amounted to almost EUR 9 billion in 2007, a time when payments under the special regime for renewable energy were still limited.

Despite the Royal Decree 1/12, the tariff deficit increased further in 2012 and reached EUR 35.6 billion by the end of February 2013 [Cne 2013]. The question remains: Is renewable electricity generation responsible for this? Despite the fact that the premium payments amounted to EUR 8.4 billion in 2012 and EUR 9.1 billion for 2013, the answer is not clear. An often neglected aspect is the fact that investment in renewable capacity has increased supply on the wholesale market, thus decreasing the system marginal price by the merit-order effect. It is argued that renewable energy 'pays for itself' because by bidding at the pool at zero prices these units substantially decrease the system marginal price. Therefore the cost of all electricity should be lower, if this price reduction is passed on to the customer. An analysis for the entire special regime concluded that for 2010 the decrease of around 29 EUR/MWh covered 70% of the FiT costs [Cia 2012a].

2.2.10 Switzerland

In 2012, about 200 MW of PV systems were installed in Switzerland, almost doubling the total capacity to 411 MW. Prices for turnkey systems decreased by over 40% in 2012 [Een 2013]. In view of the decreasing PV system prices, the FiT was reduced three times in 2012.

2.2.11 United Kingdom

The United Kingdom introduced a new FiT scheme in 2010, which led to the installation of approximately 55 MW that year and over 1 GW in 2012. This steep increase was caused by the announcement of a fast-track review of large-scale projects by the Department of Energy & Climate Change (DECC) in February 2011, which led to a rush to complete these projects in the first half of 2011 [DEC 2011]. A second rush occurred towards the end of the year to meet the deadline of 12 December 2011, 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 above 50 kWp. In November 2012, a further reduction of 3.5% for systems smaller than 50 kWp took place, whereas there was no reduction for larger systems because hardly any were installed between May and July 2012. However, for larger systems there was the possibility of receiving Renewable Obligation Certificates (ROC) – for PV the rate was 2 ROCs per MWh – until April 2013. Overall about 630 MW were installed, bringing the cumulative capacity to 1.8 GW by the end of 2012.

During 2012 the Energy and Climate Change Minister Greg Barker repeatedly declared his desire to see the UK solar market reach 22 GW by 2020.

2.2.12 Other European Countries and Turkey

In 2012 **Austria** installed about 230 W of new PV systems and more than doubled the cumulative capacity to 417 MW. The Ökostrom-Eispeisetarifverordnung 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 also an investment subsidy which has a budget of EUR 36 million for 2013. Regardless of the size of the systems, a maximum of 5 kWp are supported with 300 EUR/kWp for add-on and ground-mounted systems and 400 EUR/kWp for building-integrated systems. Operators of PV systems larger than 5 kWp can choose to opt for the so-called net-parity tariff (Netzparitäts-Tarif), for a period of 13 years. Since 1 January 2013 this option has only been available for systems on buildings.

Despite high solar radiation, solar PV system installation in **Portugal** has grown very slowly and by the end of 2012 it had reached a cumulative capacity of 229 MW.

In March 2010, the Energy Ministry of **Turkey** 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 Legislation which defines new guidelines for FiTs. The FiT is 0.133 USD/kWh (0.10 EUR/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. The first licensing round with a volume of 600 MW closed in June 2013 and was oversubscribed about 15 times with close to 9 GW of projects submitted to the Turkish Energy Regulatory Authority (EPDK). How much of this will be installed still has to be seen. At the end of 2012, around 15 MW of grid-connected and stand-alone systems were estimated to be installed cumulatively.

In 2012 Ukraine again saw an impressive growth and almost doubled its capacity with over 180 MW new installed systems to 370 MW at the end of the year. In July 2012, the Ukrainian Parliament had the first reading of a bill to simplify access by households to the feed-in scheme. The bill included a reduction in FiTs of 16% to 27%, depending on the kind of installation, and 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. Market analysts consider it possible that the cumulative installed capacity could again double in 2013.

2.3 Africa

Despite Africa's vast solar resources and the fact that in large areas the same photovoltaic panel in average can produce twice as much electricity in Africa than in Central Europe, only limited use of solar photovoltaic electricity generation is made. The main application of PV systems in Africa is in small solar home systems and the market statistics for these are extremely imprecise or non-existent. Therefore, all African countries are **potential or emerging markets** and some of them are mentioned below.

In 2011, **Algeria's** Ministry of Energy and Mines published the 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. It is estimated that about 5 MW of small decentralised systems were installed at the end of 2012. For 2013, new installations of around 20 MW are planned.

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 n1/2011 establishes the regulations for independent energy production. In particular, it establishes the framework conditions for the set-up of independent power producers using renewable energy (15 years PPA), and for self-production at user level. It creates a microgeneration 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. To achieve the 2020 50% renewable energy target, about 340 MW of PV systems are required.

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 the mitigation of 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 of 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]. In December 2012, Blue Energy of the UK 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]. These two projects are still in the development phase and looking for strategic investors. In May 2013, the Volta River Authority (VRA) inaugurated its first solar power plant at Navrongo, with a capacity of 2 MW. VRA plans to install a total of 14 MW by 2014.

In 2008, **Kenya** introduced FiTs for electricity from renewable energy sources, but solar power was only included in 2010, when the tariffs were revised [GoK 2010]. However, only a little more than 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 with an annual output of 30 000 modules in Naivasha, Kenya. The plant produces modules for smaller PV systems like the solar home systems. Current estimates of the PV market in Kenya put average annual sales of home systems at 20 000 to 30 000 and solar lanterns at 80 000.

The **Kingdom of Morocco's** solar plan was introduced in November 2009, with the aim of establishing 2 000 MW of solar power by 2020. To implement this plan, the Moroccan Agency for Solar Energy (MASEN) was founded in 2010. Both solar electricity technologies, Concentrating Solar Thermal Power (CSP) and PV, will 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 about 20 MW of PV systems installed, mainly under the Global Rural Electrification Programme (PERG) Framework and about 1 to 2 MW of grid-connected systems.

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. Two rounds have already taken place, one in 2011 and one in 2012, and the third one closed in August 2013. The overall target is 3.725 GW and the one for solar PV is 1.45 GW. In the first two bidding rounds 1 048 MW of solar PV projects were allocated to the preferred bidders. Between the first round (closing date: 4 November 2011) and the second round (closing date: 5 March 2012), the average bid price decreased from 2.65 ZAR/kWh (0.252 EUR/kWh) to 1.65 ZAR/kWh (0.157 EUR/kWh) in. It is estimated that about 30 to 40 MW of PV systems were installed in South Africa by the end of 2012.

2.4 Americas

2.4.1 Canada

In 2012, the Canadian market was about the same as the year before with 268 MW, and with this the total cumulative installed PV capacity increased to about 830 MW. This development was driven by the introduction of a FiT in the province of Ontario, enabled by Bill 150, Green Energy and Green Economy Act, 2009. More than 77% of the total capacity is installed in Ontario. On the federal level, there is only an accelerated capital cost allowance under the Income Tax Regulations. On a provincial level, nine Canadian provinces have Net Metering Rules, with solar PV electricity as one of the eligible technologies, Sales Tax Exemptions and Renewable Energy Funds exist in two provinces, and Micro Grid Regulations and Minimum Purchase Prices each exist in one province.

The Ontario FiTs were set in 2009, depending on the system size and type and they were reduced in various steps. In June 2013, the Minister of Energy announced an annual cap of 150 MW for the small FiT regime and 50 MW for the micro FiT regime for the next four years, with a transition in 2013. This means that systems larger 500 kW are no longer eligible for the FiT. Following the WTO ruling in May on local content regulations, the Minister said that Ontario will comply with it.

2.4.2 United States of America

With over 3.3 GW of newly installed PV capacity, the United States reached a cumulative PV capacity of 7.7 GW (7.2 GW grid-connected) at the end of 2012. Utility PV installations again more than doubled compared to 2011, and they became the largest segment with 1.7 GW in 2012. The top ten States – California, Arizona, New Jersey, Nevada, North Carolina, Hawaii, Maryland, Texas and New York – accounted for more than 88% of the US PV market [Sei 2013]. For 2013, the estimated market growth is around 30%.

PV projects based on PPAs, with a total capacity of 10.5 GW, are already under contract and over 3 GW of these projects are already financed and under construction [Sei 2013]. If one includes those projects in an earlier development stage, the pipeline stands at almost 22 GW.

Many state and federal policies and programmes have been adopted to encourage the development of markets for PV and other renewable technologies. These consist of 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 US is maintained by the Solar Centre of the State University of North Carolina. The Database of State Incentives for Renewable Energy (DSIRE) is a comprehensive source of information on state, local, utility, and selected federal incentives that promote renewable energy. It 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.

2.4.3 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 2012, about 17 MW (7 MW grid-connected) 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 2020 [Ern 2011].

At the end of 2012, **Brazil** had about 20 MW of cumulative installed capacity of PV systems, mainly in rural areas. 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 rule applies to generators that use subsidised sources of energy (hydro, solar, biomass, co-generation and wind). Over 2 GW of PV projects have applied for approval. At the end of 2012, it was estimated that about 40 MW (6.6 MW grid-connected) had been installed. In its mid-term market report, the IEA forecasts a cumulative installed PV capacity of about 200 MW for 2013 and 1.2 GW by 2018 [IEA 2013].

In February 2012, the President of **Chile**, President Piñera, announced a strategic energy plan for achieving 20% of non-conventional renewable energy by 2020. Legislation to reach this 20% target is currently under consideration. In the first quarter of 2012, the first MW size PV system was installed in the northern Atacama Desert. In June 2013, Chile's Environmental Assessment Service (SEA) approved over 4 GW of projects with an additional 2.2 GW still under review. It is estimated that about 10 MW of PV systems (5 MW grid-connected) were installed by the end of 2012. In June 2013, about 70 MW of PV systems were under construction and it is expected that about 50 MW of new systems will be operational by the end of 2013.

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 there were about 1 to 2 MW of solar PV systems were installed in rural areas, which increased to over 5 MW in 2011. In 2011, the first PPA for 54 MW was signed between Grupo de Empresas Dominicanas de Energía Renovable and Corporación Dominicana de Empresas Eléctricas Estatales (CDEEE). The first phase of the project (200 kW) became operational in July 2012 and the full capacity should be connected to the grid in the second half of 2013. In 2012, CDEEE signed two more PPAs with a total capacity of 116 MW.

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 decrease 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.

At the end of 2012, about 52 MW of PV systems had been installed, according to the IEA PVPS [IEA 2013b].

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 of bidding 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. It may be possible to double the capacity in 2013.

3. ELECTRICITY COSTS AND ECONOMICS OF PV SYSTEMS

Over the last four decades, solar module prices have decreased 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 decreased by 20 % for each doubling of production volume (Fig. 6). This development was driven not only by technological developments but also market conditions. It is interesting to note that between 2004 and the second half of 2008 the price of PV modules remained pretty constant at between 4 and 4.5 USD_{2012}/Wp. This happened despite the fact that manufacturing technology continuously improved and companies significantly scaled up production. The reason was the expanding markets in Germany and Spain, where the FiTs enabled project developers to be profitable at that price, coupled with the temporary shortage of polysilicon between 2004 and 2009, which limited silicon production and prevented effective pricing competition, so 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 %.

Between 2008 and the end of 2012, there has been a massive drop in the price of modules of 80 %, with 20 % in 2012 alone, creating serious financing problems for all companies and leading to the closure of a significant number of them [Blo 2013a].

PV system prices have followed the reduction in module prices but at a slower pace. This becomes obvious if one looks at the share of the PV module in the system price, which shifted from almost 70 % in 2008 to less than 50 % in 2013.

Despite the fact that a global market exists for the hardware components of a PV system, e.g. modules, inverters, cables, etc., and prices are very similar worldwide, the prices for installed PV systems still vary significantly. The reasons for these differences are manifold and range from the different legal requirements for permitting, licensing and connection to the grid to the different maturity of the local PV market, with impacts on competition between system developers and installers. The price of PV system prices is changing rapidly, not only in Europe, and this could well open up new opportunities for photovoltaics to become one of the major electricity providers in the near future.

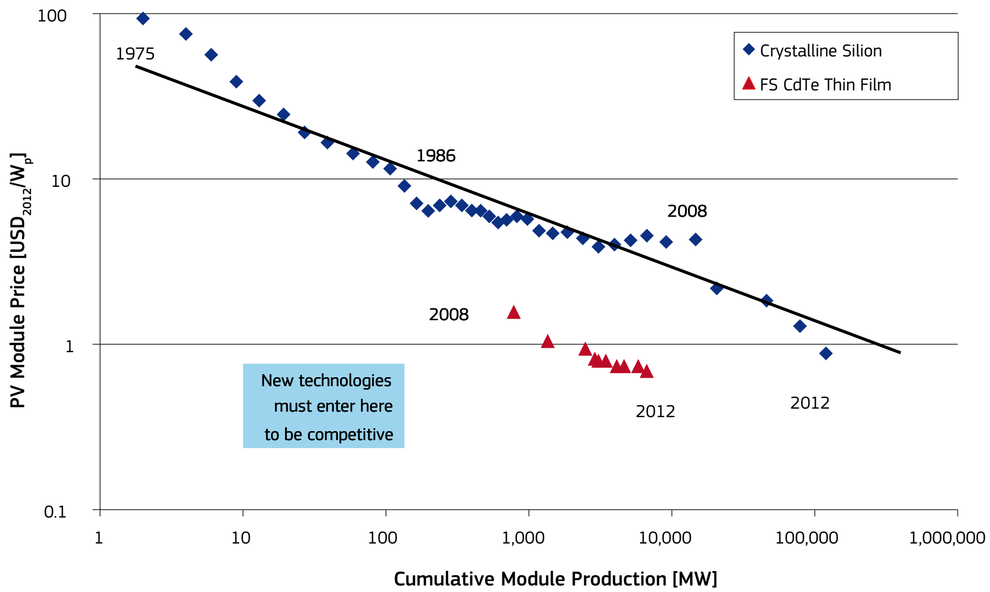


Fig. 6: Price-experience curve for solar modules (data source: Bloomberg New Energy Finance and PV News)

3.1 Levelised Cost of Electricity

A common measure for the comparison of power generation technologies is the concept of Levelised Cost of Electricity (LCOE)[16]. LCOE is the price at which electricity must be generated from a specific source to break even over the lifetime of the project. It is an economic assessment of the cost of the energy generating system, including all the costs over its lifetime: initial investment, operations and maintenance, cost of fuel and cost of capital. It can be calculated using a single formula as:

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

with

- 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

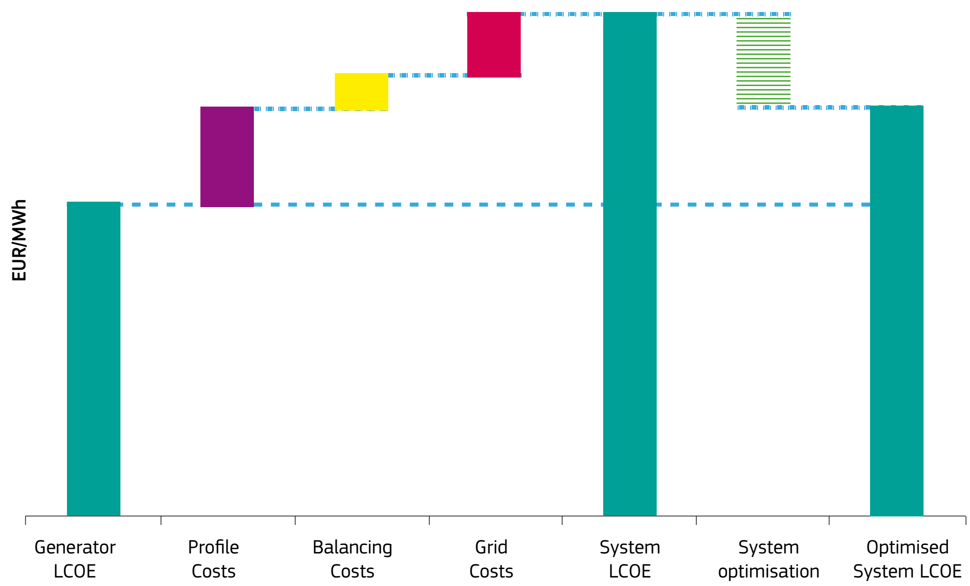
This calculation delivers the LCOE of the generator, but falls short of describing the full LCOE for the total system, which includes profile cost (including flexibility and utilisation effects), balancing costs and grid costs. These cost categories have to be added to all LCOEs of electricity generating technologies whether they are conventional or renewable energy sources (Fig. 7). There are a number of reasons why the LCOEs of different power generation technologies are different in different regions and at different times, and this has an influence on the merit-order effect. Examples:

- 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.
- 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.
- Demand variations.
- Central or decentralised power generation.
- Weather forecasting accuracy for wind and solar.
- Market regulations and trading opportunities. Etc.

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

A considerable number of studies have calculated, estimated or modelled the value of renewable electricity from variable resources, but most of them investigated the market penetration of a single renewable energy source like wind or solar and not a portfolio of different renewable energy sources and optimised integration technology options [Hir 2013 and references, Uec 2013].

Fig. 7: System LCOE



16) LCOE formula used by NREL:
http://www.nrel.gov/analysis/tech_lcoe_documentation.html

For solar PV electricity the market value depends on the kind of application. For 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. 8. The increase in PV system prices in Japan between 2007 and 2010 is due to changes in exchange rates; in the local currency the prices decreased further.

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 just 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 to use– contract, wholesale or day-ahead prices. The fact that the costs of PV-generated electricity can be equal or lower than residential electricity costs is not yet sufficient to support a self-sustained and unsupported market.

In June 2013, the worldwide average price of a residential system without tax was given as 1.97 USD/Wp (1.54 EUR/Wp) [Pvi 2013]. Taking this price and adding a surcharge of 0.16 EUR/Wp for fees, permitting, insurance, etc., an installed PV system costs 1 700 EUR/kWp without financing and VAT. The breakdown of costs is depicted in Fig. 9.

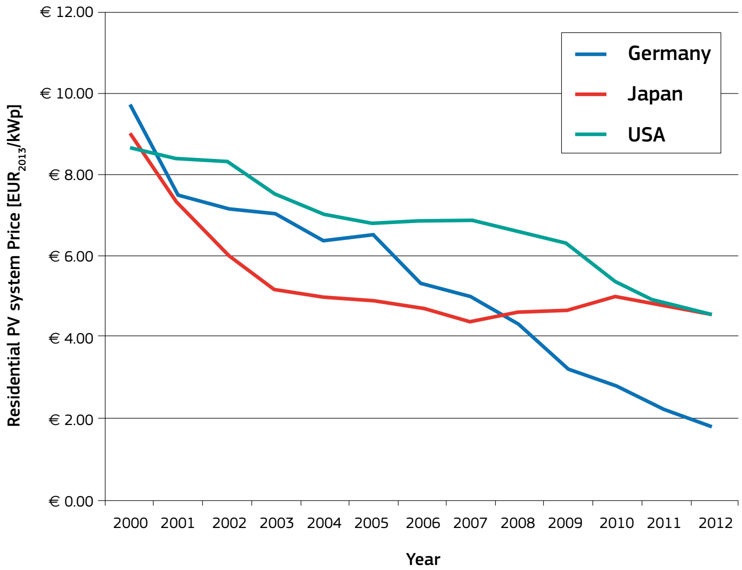


Fig. 8: Residential PV system price development over the last decade (data sources: IEA PVPS, BSW, DoE Sun-Shot Initiative, Eurostat, OECD key economic data)

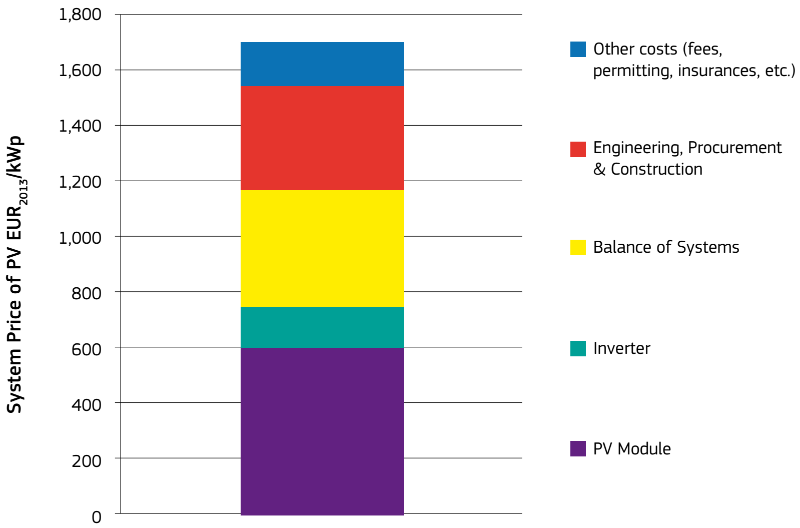


Fig. 9: Price breakdown of residential PV system

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 permitting costs, they comprise one-third of the electricity generation costs from a residential PV system for the first 20 years (Figs. 10 and 11).

Depending on the actual radiation level, the 1.5% operation, maintenance and repair (O&M) costs are the second or third largest cost factor. 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 1.5 EUR cent/kWh on top of the 2.5 EUR cent /kWh results in an electricity price of 4.0 EUR cent/kWh after the 20-year financial payback period.

In 2013, the average residential electricity rate in Australia is about 0.27 AUD/kWh (0.19 EUR/ kWh), but for customers with peak tariffs this can increase to 0.39 AUD/kWh

Table 1: LCOE of PV-generated electricity for residential systems with a system price of 1 700 EUR/kWp (excluding VAT, because the differences in the various countries are too large), 1.5% O&M cost, an annual generation of 1 000 kWh/ kWp/year and a financial lifetime of 20 years.

	Price [EUR/ kWp]	LCOE Product [EUR cent/ kWh]	LCOE Capital [EUR cent/kWh]			LCOE O&M 1.5% [EUR cent/ kWh]	LCOE Total [EUR cent/kWh]		
Return on Investment		0%	3%	5%	10%		3%	5%	10%
PV Module	600	3.0	0.9	1.6	3.4	0.9	4.8	5.5	7.3
Inverter	150	0.75	0.25	0.35	0.85	0.2	1.2	1.3	1.8
Balance of Systems	420	2.1	0.6	1.1	2.4	0.6	3.3	3.8	5.1
Engineering Procurement & Construction	370	1.85	0.55	0.95	2.15	0.6	3.0	3.4	4.6
Other costs (fees, permitting, insurance, etc.)	160	0.8	0.2	0.4	0.9	0.2	1.2	1.4	1.9
Total	1 700	8.5	2.5	4.4	9.7	2.5	13.5	15.4	20.7

Fig. 10: LCOE cost shares for 5 % ROI

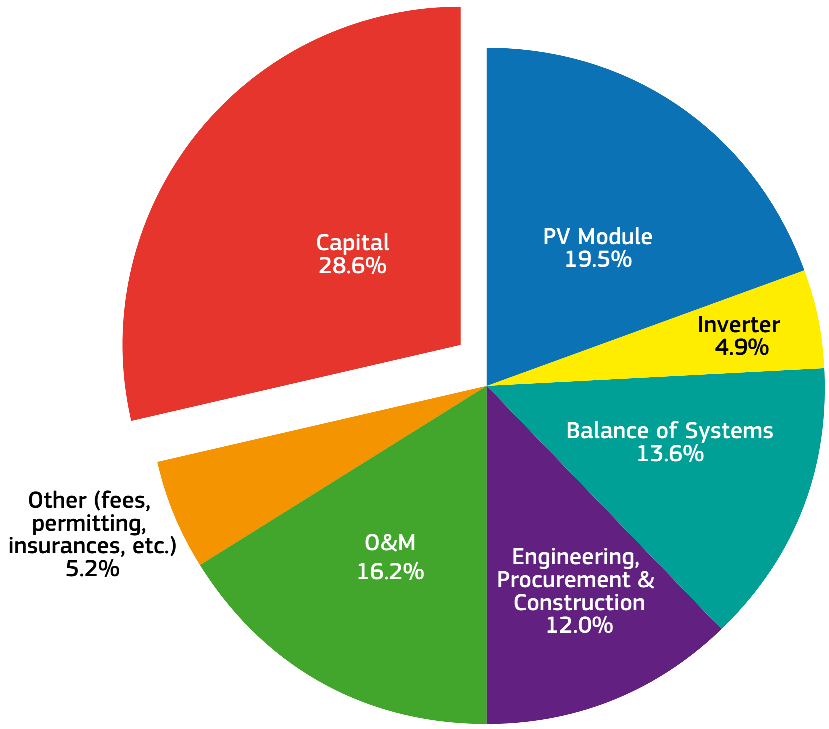


Table 2: LCOE of PV-generated electricity for residential systems with a system price of 1 700 EUR/kWp (excluding VAT, because the differences in the various countries are too large), 1.5 % O&M costs, an annual generation of 1 300 kWh/kWp/year and financial lifetimes of 20 years.

	Price [EUR/kWp]	LCOE Product [EUR cent/kWh]	LCOE Capital [EUR cent/kWh]			LCOE O&M 1.5 % [EUR cent/kWh]	LCOE Total [EUR cent/kWh]		
Return on Investment		0 %	3 %	5 %	10 %		3%	5%	10%
PV Module	600	2.3	0.7	1.2	2.6	0.7	3.9	4.4	5.8
Inverter	150	0.6	0.2	0.3	1.6	0.2	1.0	1.1	1.4
Balance of Systems	420	1.6	0.5	0.9	1.8	0.5	2.7	3.1	4.0
Engineering Procurement & Construction	370	1.4	0.5	0.8	1.6	0.4	2.5	2.8	3.6
Other costs (fees, permitting, insurance, etc.)	160	0.6	0.2	0.3	0.7	0.2	1.0	1.1	1.5
Total	1 700	6.5	2.1	3.5	7.5	2.0	10.6	12.0	15.4

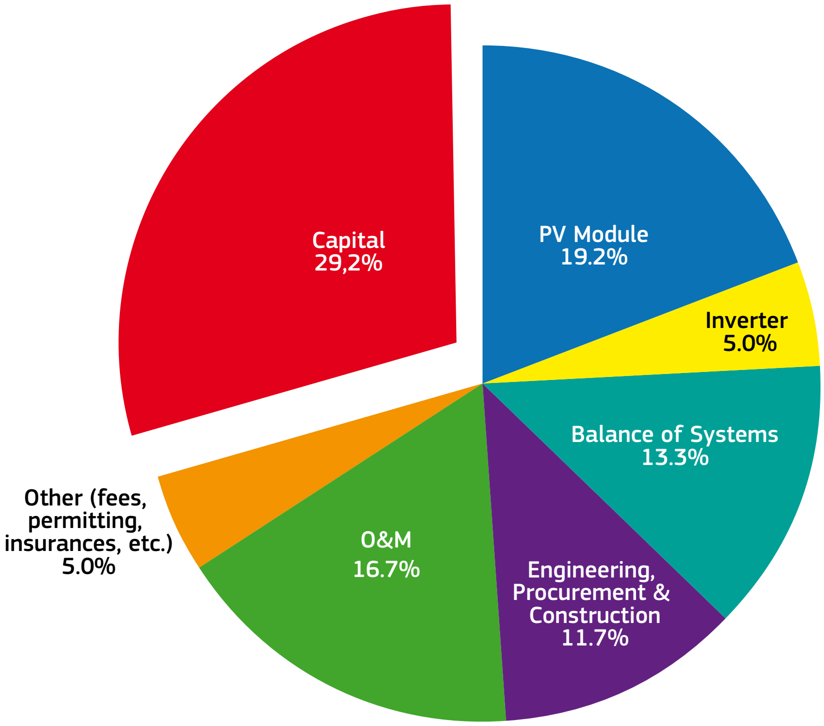


Fig. 11: LCOE cost shares for 5 % ROI

(0.27 EUR/kWh) between 14.00 and 20.00, a good match with PV electricity generation. The average European residential electricity price given by EUROSTAT for the second semester of 2012 was 0.197 EUR/kWh and higher than PV-generated electricity for the lower ROI financing options, which are more realistic for private consumers [Est 2013]. Denmark, Cyprus, and Estonia together with Germany had the highest prices with 0.297 EUR/kWh, 0.291 EUR/kWh and 0.268 EUR/kWh respectively. It should be mentioned that the LCOE in Cyprus is more than 20 % lower due to the higher solar radiation. In April 2013, Japan's largest utility Tokyo Electric Power Company (TEPCO) increased its prices to 18.89 JPY/kWh (0.145 EUR/kWh) for the first 120 kWh per month, 25.19 JPY/kWh (0.199 EUR/kWh) for everything above 120 kWh and below 300 kWh per month, and 29.10 JPY/kWh (0.224 EUR/kWh) for every kWh above 300 kWh per month. In August 2013, a fuel surcharge of 1.89 JPY/kWh (0.015 EUR/kWh) was added [Tep 2013].

Without support, the profitability of a solar PV system primarily depends on self-consumption by the owner, 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 just 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 to use – contract, wholesale or day-ahead prices.

As an example, Table 3 shows at what price the surplus electricity has to be sold in Europe to break even with an ROI of 3 %. The average annual electricity consumption of European households is about 3 500 kWh and would require a PV system of 3.5 kWp.

Table 3: Necessary selling price of PV electricity to break even with a system price of 1 700 EUR/ kWh (excluding VAT), 1.5 % O&M cost, ROI of 3 % and a 20-year financial payback period in Europe.

The first option for improving profitability is to increase self-consumption by demand shifting and using electrical appliances like the

Table 3: Necessary selling price of PV electricity to break even with a system price of 1 700 EUR/kWh (excluding VAT), 1.5 % O&M cost, ROI of 3 % and a 20-year financial payback period in Europe.

	Without PV system	With PV system
Purchase from utility (kWh)	3 500	2 450
Own PV electricity use (kWh)		1 050
PV electricity generation costs at 1 000 kWh/kWp (EUR)		472.50
PV electricity generation costs at 1 300 kWh/kWp (EUR)		371.00
Retail electricity price European average (EUR/kWh)	0.197	0.197
Electricity bill European average (EUR)	689.50	482.65
Necessary selling price of PV electricity to break even at 1 000 kWh/kWp (EUR/kWh)		0.110
Necessary selling price of PV electricity to break even at 1 300 kWh/kWp (EUR/kWh)		0.067
Retail electricity price Denmark (EUR/kWh)	0.297	0.297
Electricity bill Denmark (EUR)	1 039.50	727.65
Necessary selling price of PV electricity to break even at 1 000 kWh/kWp (EUR/kWh)		0.066
Retail electricity price Cyprus (EUR/kWh)	0.291	0.291
Electricity bill Cyprus (EUR)	1 018.50	712.95
Necessary selling price of PV electricity to break even at 1 300 kWh/kWp (EUR/kWh)		0.027
Retail electricity price Estonia, Germany (EUR/kWh)	0.268	0.268
Electricity bill Estonia, Germany (EUR)	938.00	656.60
Necessary selling price of PV electricity to break even at 1 000 kWh/kWp (EUR/kWh)		0.080

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 this is still a relatively expensive option, with the price for electricity from storage at 0.18 to 0.21 EUR/kWh, which has to be added to the PV LCOE. The current investment costs for a residential battery storage system are about 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 and so lower the costs significantly.

A 2012 business analysis for electric vehicles by McKinsey showed that the 2012 price of lithium-ion batteries in the range 500 to 600 USD/kWh (385 to 460 EUR/kWh) storage capacity could fall to 200 USD/kWh (155 EUR/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 0.10 to 0.12 USD/kWh (0.077 to 0.093 EUR/kWh) and should fall to 0.04 USD/kWh (0.03 EUR/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.

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 of such systems 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. With the burst of the Spanish bubble 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.

Due to the plant size, up to 250 MW at the moment, the cost structure and LCOE is quite different from residential PV systems. Fig. 12 shows the average cost breakdown in competitive markets. The actual cost breakdown differs from project to project and in 2013 Engineering, Procurement and Construction (EPC) quotes for large systems as low as 0.8 EUR/Wp (1.04 USD/Wp) have been reported, but these will yield almost no margin and it has to be seen if they will become impossible after the trade agreement between China and the European Union [Blo 2013b].

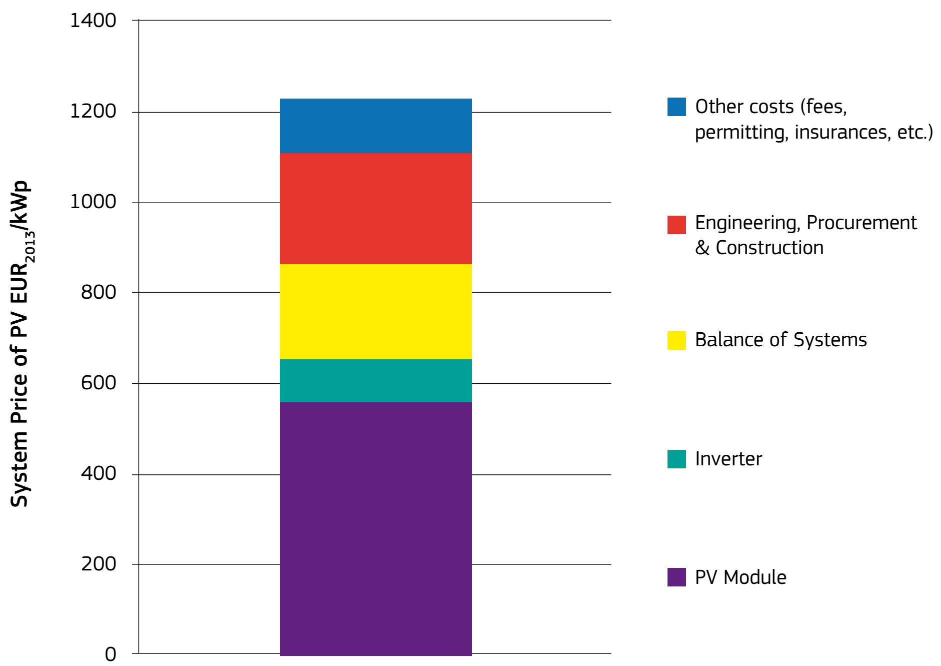


Fig. 12: Price breakdown of utility-scale PV system

Already in 2010, Ken Zweibel published an analysis 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 2.00 USD_{2010}/Wp (1.54 EUR_{2010}/Wp) should be possible. The 2013 market is expected to be still smaller, but current utility system prices at 1 220_{2013}EUR/kWp (1810_{2010}USD/kWp[17]) are already below this level.

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

Table 4: LCOE of PV-generated electricity for utility-scale systems with a system price of 1 220 EUR/kWp, 1.5% O&M costs, an annual generation of 1 000 kWh/kWp/year and financial lifetimes of 20 years.

	Price [EUR/kWp]	LCOE Product [EUR cent/kWh]	LCOE Capital [EUR cent/kWh]			LCOE O&M 1.5% [EUR cent/kWh]	LCOE Total [EUR cent/kWh]		
Return on Investment		0%	3%	5%	10%		3%	5%	10%
PV Module	560	2.8	0.9	1.5	3.2	0.8	4.5	5.1	6.8
Inverter	90	0.5	0.1	0.2	0.5	0.1	0.7	0.8	1.1
Balance of Systems	210	1.1	0.3	0.5	1.1	0.3	1.7	1.9	2.5
Engineering Procurement & Construction	240	1.2	0.4	0.6	1.4	0.4	2.0	2.2	3.0
Other costs (fees, permitting, insurance, etc.)	1 220	0.6	0.2	0.3	0.7	0.2	1.0	1.1	1.5
Total	1 220	6.1	1.9	3.2	6.9	1.8	9.8	11.2	14.9

Table 5: LCOE of PV-generated electricity for utility-scale systems with a system price of 1 220 EUR/kWp, 1.5% O&M costs, an annual generation of 1 300 kWh/kWp/year and financial lifetimes of 20 years.

	Price [EUR/kWp]	LCOE Product [EUR cent/kWh]	LCOE Capital [EUR cent/kWh]			LCOE O&M 1.5% [EUR cent/kWh]	LCOE Total [EUR cent/kWh]		
Return on Investment		0%	3%	5%	10%		3%	5%	10%
PV Module	560	2.2	0.6	1.1	2.4	0.6	3.5	3.9	5.2
Inverter	90	0.3	0.2	0.2	0.4	0.1	0.6	0.6	0.8
Balance of Systems	210	0.8	0.3	0.4	0.9	0.2	1.3	1.4	1.9
Engineering Procurement & Construction	240	0.9	0.3	0.5	1.1	0.3	1.5	1.7	2.3
Other costs (fees, permitting, insurance, etc.)	120	0.5	0.1	0.2	0.4	0.1	0.7	0.8	1.0
Total	1 220	4.7	1.4	2.5	5.3	1.3	7.5	8.6	11.4

17) United States inflation see: http://www.usinflationcalculator.com/inflation/historical-inflation-rates/

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 57.90 USD/MWh (44.54 EUR/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 27 USD/MWh (20.77 EUR/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, 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 probably be necessary to add (super)-capacitor and battery manufacturers as well as power electronics and IT providers for managing supply and demand and meteorological forecasts. The main focus in this report, however, will be on solar cell and module manufacturers and polysilicon manufacturers.

In 2012, the PV world market grew by 10% in terms of solar cell **production** to about 38.5 GW. The market for installed systems grew by almost 30% and values between 29 and 31 GW were reported by various consultancies and institutions. This mainly represents the grid-connected PV market. To what extent the off-grid and consumer-product markets are included is unclear. The difference of roughly 7 to 9 GW therefore has to be explained as a combination of unaccounted off-grid installations (ca. 100 – 200 MW off-grid rural, ca. 100 – 200 MW communication/signals, ca. 100 MW off-grid commercial), consumer products (ca. 100 – 200 MW) and cells/modules in stock.

In addition, the fact that some companies report shipment figures, some report sales figures and others report production figures, adds to the uncertainty. An additional error source is 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 decreased 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, has overcompensated for this between 2008 and 2012. The announced production capacities – based on a survey of more than 300 companies worldwide – increased again in 2012 but much less than the years before. For 2013 no significant capacity increase is expected, but the return to manufacturing capacity growth is possible in 2014, which would ease the difficult situation of equipment manufacturers. However, the rapid changes in the sector and the difficult financing situation make a reasonable forecast for future capacity developments very speculative. It is believed that the current situation of overcapacities in the solar cell manufacturing capacities will continue at least until 2015, when the global PV market should exceed 50 GW of new installations annually.

4.1 Technology Mix

After the temporary silicon shortage between 2004 and 2008, silicon prices fell dramatically and the cost of wafer-based silicon solar cells decreased very rapidly. In 2012, their market share was close to 90% and now they are 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 manufacturing capacity increases for both technologies were followed by the capacity expansions needed for polysilicon raw materials.

In 2005, for the first time, production of thin-film solar modules reached more than 100 MW per annum. Between 2005 and 2009, the 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 16% to 20% in 2009. Since then, the thin-film share has been slowly decreasing as the ramp-up of new production lines did not follow that of wafer-based silicon.

The majority of thin-film companies are 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 companies use CdTe or dye and other materials.

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

Within CPV there is a differentiation according to concentration factors[18] 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 the system integration. However, it should be pointed out that CPV is just at the beginning of an industry learning curve, with considerable potential for technical and cost 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 so benefit from economies of scale.

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

The existing PV technology mix is a solid foundation for future growth of the sector as a whole. No single technology can satisfy all the different consumer needs, ranging from mobile and consumer applications, with the need for a few watts 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 is an insurance against any stumbling blocks in the implementation of solar PV electricity.

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

4.2 Solar Cell Production[19] Companies

Worldwide, more than 350 companies produce solar cells. The solar cell industry has been very dynamic over the last decade, but the changes that have taken place since 2011 give only a snapshot of the current situation, which may change in just a few weeks. Despite the fact that a few dozen companies filed for insolvency, scaled back, idled or stopped production, the number of newcomers and their planned capacities is still exceeding the retired capacity.

The following section gives a short description of the 20 largest companies, in terms of actual production/shipments in 2012. 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 of the respective companies or the references cited.

4.2.1 Yingli Green Energy Holding Company 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-New Tech Industrial Development Zone. The company's operations include solar wafers, cell manufacturing and module production. According to the company, production capacity reached 1.85 GW at the end of 2011. In its 2012 annual report, the company reported that by the end of 2012 it had a capacity of ingot, 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 companies. For 2012, total reported shipments of solar modules were 2.3 GW. Solar cell production is estimated at 1 950 MW for 2012.

In January 2009, Yingli acquired Cyber Power Group Limited, a development stage enterprise created to produce polysilicon. Through its principle operating subsidiary, Fine Silicon, the company started trial production of solar-grade polysilicon in late 2009, and at the end of 2011 it was still ramping up to a full production capacity of 3 000 tonnes per year. However, the

19) **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.

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, the Ministry of Science and Technology of China 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 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. The company currently has three manufacturing sites – in Perrysburg (United States), Frankfurt/Oder (Germany) and Kulim (Malaysia) – which at the end of 2011 had a combined capacity of 2.376 GW. The second Frankfurt/Oder plant, which doubled the capacity there to 528 MW, became operational in May 2011 and the expansion in Kulim increased the production capacity there to 1.584 GW at the end of 2011. In April 2012, the company announced a major restructuring to respond to the changing market conditions [Fir 2012]. It announced it would close the factory in Frankfurt/Oder at the end of 2012 and idle four production lines in Kulim. In addition, it put the factory in Meza (Arizona), United States, on hold, and sold the factory already built in the Dong Nam Industrial Park, Vietnam.

In 2012, the company produced 1.875 GW. For the first quarter of 2013, the company reported production costs of 0.69 USD/Wp (0.53 EUR/Wp), including under-utilisation and upgrading costs of 0.05 USD/Wp (0.038 EUR/Wp).

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 Australia PV Science and Engineering Company. Commercial operation started in April 2006 and the company went public on 7 February 2007. According to the company, at the end of 2012 the production capacity was 2.5 GW for cells, 1.8 GW for modules and 1 GW for wafers. For 2012, sales of 1.7 GW were reported.

4.2.4 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 annual report of the company, the production capacity was 1.2 GW for ingots and wafers and 2.4 GW for cells and modules at the end of 2012 . For 2012, shipments of 1.6 GW were reported.

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.

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

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. Hanwha SolarOne 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, the company 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 2.3 GW of solar cells (1.3 GW in China, 800 MW in Malaysia and 200 MW in Germany). In addition, Hanwha SolarOne has 800 MW of ingot and wafer production capacity. For 2012, Hanwha SolarOne reported shipments of 830 MW and Hanwha Q CELLS reported an additional solar cell production of 570 MW [Ikk 2013a].

4.2.6 Suntech Power Co. Ltd (China)

Suntech Power Co. Ltd (http://www.suntech-power.com) is located in Wuxi. It was founded in January 2001 by Dr Zhengrong Shi and went public in December 2005. Suntech specialises in the design, development, manufacturing and sale of PV cells, modules and systems.

In its preliminary financial statement, Suntech reported shipments of 1.8 GW for 2012. External reports gave the cell production as 1.35 GW [Pvn 2013].

Due to financial problems, Wuxi Suntech Power Co. Ltd ('Wuxi Suntech'), the Chinese subsidiary of Suntech Power Holdings Co. Ltd, filed a petition for insolvency and restructuring with Wuxi Municipal Intermediate People's Court in Jiangsu Province, China, which was accepted on 20 March 2013.

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. The 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 2012 was given as 1.6 GW. For 2012, a total shipment of 1.28 GW was reported.

4.2.8 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, 1.6 MW cell capacity and 2.4 GW module manufacturing capacity (2.1 GW in China and 330 MW in Ontario, Canada). For 2012, the company reported sales of 1.47 GW of modules, but no cell production figure was given, which must be lower, because the company states in its financial reports that it buys cells from other manufacturers. External reports gave the cell production as 1.24 GW [Pvn 2013].

4.2.9 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 1 170 MW at the end of 2011. The company expanded its capacity to 1.5 GW in 2012. In 2012, the company had a production of 1.1 GW [Pvn 2013].

4.2.10 JinkoSolar Holding Co., Ltd. (China)

JinkoSolar (http://www.jinkosolar.com/) was founded by HK Paker Technology Ltd in 2006. Starting from the upstream business, the company expanded operations across the solar value chain, including recoverable silicon materials, silicon ingots and wafers, solar cells and modules in 2009. In May 2010, the company went public and is now listed on the New York Stock Exchange. According to the annual report, the company had manufacturing capacities of 1.2 GW each for wafers, solar cells and solar modules at the end of 2012. For 2012, the company reported sales of about 1.2 GW (912 MW modules, 84 MW cells and 190 MW wafers).

4.2.11 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. Production capacity of silicon solar cells at the end of 2012 was 1.3 GW. In 2012, the company had a production of about 958 MW [Pvn 2013]. In 2013, the company merged with DelSolar to become the largest Taiwanese cell producer.

4.2.12 SunPower Corporation (USA/Philippines/Malaysia)

SunPower (http://us.sunpowercorp.com/) was founded in 1988 by Richard Swanson and Robert Lorenzini, to commercialise proprietary high-efficiency silicon solar cell technology. The company went public in November 2005. SunPower 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.

SunPower conducts its main R&D activity in Sunnyvale (California) United States, and has its cell manufacturing plants in the Philippines and Malaysia. In 2011, the company had two cell manufacturing plants outside Manila, but decided to close down Fab. N° 1 in early 2012. Fab. N° 1 had a nameplate capacity of 125 MW and Fab. N° 2 has a nameplate capacity of 575 MW. Fab. N° 3, a joint venture with AU Optronics Corporation (AUO), had a capacity of 1.4 GW at the end of 2012.

The company has two solar module factories in the Philippines (600 MW) and since 2011, also Mexico (500 MW). In addition, modules are also assembled for SunPower by third-party contract manufacturers in China, Mexico, Poland and California. Total cell production in 2012 was reported at 925 MW.

4.2.13 Hareon Solar Technology Co. Ltd (China)

Hareon Solar (http://www.hareonsolar.com) was established 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 2012 the production capacity was to be increased to over 2 GW for cells and 1 GW for modules. For 2012, a production of 900 MW is reported [Pvn 2013].

4.2.14 Kyocera Corporation (Japan, Czech Republic, Mexico)

In 1975, Kyocera (http://global.kyocera.com/prdct/solar/) began with research on 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, Kyocera became the first Japanese company to sell home PV generation systems.

Besides the 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, Shiga Prefecture, is active in R&D as well as the manufacturing of solar cells, modules, equipment parts, and devices which exploit heat.

In 2012, Kyocera had a production of 800 MW and is planning to increase its capacity to 1 GW in 2013 [Ikk 2013a].

4.2.15 Renewable Energy Corporation AS (Norway/Singapore)

REC's (http://www.recgroup.com/) vision 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, REC 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, the company 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 Glomfljord 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 site for producing wafers, solar cells and modules, with a capacity of 750 MW. In 2012, production was reported at 750 MW.

4.2.16 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 the company, at the end of 2012 it had a production capacity of 2 GW of wafers, 1.2 GW of modules and 800 MW of solar cells. Shipments for 2012 are reported as 1.5 GW for wafers and 710 MW for modules.

4.2.17 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, the company had a production capacity of 1 GW across the complete value chain of ingots, wafers, cells and modules at the end of 2011. For 2012, sales of 600 MW were reported [Enf 2013].

4.2.18 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 the 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 and increased to 75 MW in early 2011. For 2012, total production capacity was reported at 800 MW and production at 584 MW [Enf 2013].

4.2.19 Solar Frontier (Japan)

Solar Frontier is a 100% subsidiary of Showa Shell Sekiyu K.K. In 1986, Showa Shell Sekiyu started to import small modules for traffic signals, and started module production in Japan, cooperatively with Siemens (now Solar World). The company developed CIS solar cells and in October 2006 it completed the construction of the first factory with 20 MW capacity in Miyazaki Prefecture. Commercial production started in FY 2007. The second Miyazaki factory (MP2), with a production capacity of 60 MW, started manufacturing in 2009. In July 2008, the company announced they 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 the year overall capacity was 980 MW. In 2011, the company changed its name to Solar Frontier. Production was reported at 450 MW [Rts 2012]. For 2012, a moderate increase to above 500 MW was estimated. 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.

4.2.20 Jiangxi Risun Solar Energy Co. Ltd (China)

Risun Solar Technologies was established in 2008. The company manufactures mono- and multicrystalline solar cells and modules. According to the company, the production capacity is 700 MW for solar cells and 300 MW for modules. An expansion to 3 GW is planned without a specified date. For 2012, a production of 500 MW was reported [Enf 2013].

4.3 Polysilicon supply

The rapid growth of the PV industry since 2000 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 500 USD/kg and consequently resulted in higher prices for PV modules. This extreme price hike triggered a massive capacity expansion, not only of established companies, but many new entrants as well. The top 10 silicon manufacturers produced about two-thirds of the total 2011 production.

The massive production expansions, as well as the difficult economic situation, led to a price decrease throughout 2009, reaching about 50-55 USD/kg at the end of 2009, with a slight upwards tendency throughout 2010 and early 2011, before prices dropped significantly. In August 2012, prices were in the 30 USD/kg (23 EUR/kg) range for contracted silicon and 20 USD/kg (15 EUR/kg) on the spot market.

Projected silicon production capacities in 2013 vary between 290 000 tonnes [Blo 2013a] and 409 690 tonnes [Ikk 2013]. It is estimated that about 27 000 tonnes will be used by the electronics industry. The possible solar cell production will, in addition, depend on the material used per Wp. The current worldwide average is about 5.6 g/Wp.

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 3 000 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 and China is aiming for large companies with at least 50 000 tonnes annual capacity by 2015. These two framing conditions, in addition to the enormous price pressure, are the reasons why a significant number of Chinese manufactures closed down their production in the first half of 2012. It is also why China imported 83 000 tonnes of silicon in 2012, 32% more than 2011 [Blo 2013g].

4.3.1 Silicon production processes

The high growth rates of the PV industry and the 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 scheme based on fluidised bed

(FB) reactors. Improved versions of these two types of processes will very probably be the workhorses of the polysilicon production industry in the near future.

Siemens process – The Siemens reactor was developed in the late 1950s and it has been the dominant production route ever since. In 2009, about 80% of total polysilicon manufactured worldwide was made with a Siemens-type process. The Siemens process involves deposition of silicon from a mixture of purified silane or trichlorosilane gas, with an excess of hydrogen, onto high-purity polysilicon filaments. The silicon growth then occurs 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 1 100 and 1 175 ºC at which trichlorosilane, with the help of the hydrogen, decomposes to elemental silicon and deposits as a thin-layer film onto the filaments. Hydrogen chloride is formed as a by-product.

The most critical process parameter is temperature control. The temperature of the gas and filaments must be high enough for the silicon from the gas to deposit onto the solid surface of the filament, but well below the melting point of 1 414 ºC, so that the filaments do not start to melt. Secondly, the deposition rate must be well controlled and not too fast, because 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 a 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 ºC, 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 continuously removed.

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. Several 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 as well.

Upgraded metallurgical grade (UMG) silicon was seen as one option for producing cheaper solar grade silicon with 5- or 6-nines purity, but the support for this technology is waning in an environment where higher-purity methods are cost-competitive. A number of companies 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

Worldwide more than 100 companies produce or have started up polysilicon production. The following list gives a short description of the 10 largest companies in terms of production in 2011. More information about other polysilicon companies can be found in various market studies.

4.4.1 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 15 000 tonnes of capacity. The ground breaking of the new 18 000 tonne factory took place in April 2011, and the construction should be finished at the end of 2013. In addition, in 2012 the company expanded the capacity of its factory in Burghausen by 5 000 tonnes, and together with a further expansion of the Nünchritz factory by 5 000 tonnes, the company plans to have 70 000 tonnes of production capacity in 2014. In 2012, total polysilicon sales were reported at 38 000 tonnes.

4.4.2 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 1 500 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. For 2012, the company reported a production of 37 055 tonnes of polysilicon and 5.6 GW of wafers.

The company also invested in the downstream business of solar. 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.

4.4.3 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 the fields of inorganic chemicals, petro and coal chemicals, fine chemicals, and renewable energy materials. In 2006, the company started its polysilicon business and successfully completed its 6 500 tonne P1 plant in December 2007. The 10 500 tonne P2 expansion was completed in July 2009, and P3 with another 10 000 tonnes brought the total capacity to 27 000 tonnes at the end of 2010. The debottlenecking 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 price decline of polysilicon. Instead the company is pursuing a further debottlenecking of the existing plants to increase capacity by 10 000 tonnes by 2013. For 2012, a production of 33 000 tonnes is 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.

4.4.4 Hemlock Semiconductor Corporation (USA)

Hemlock Semiconductor Corporation (http://www.hscpoly.com) is based in Hemlock, Michigan. The corporation is a joint venture between Dow Corning Corporation (63.25 %) and two Japanese firms, Shin-Etsu Handotai Company Ltd (24.5 %) and Mitsubishi Materials Corporation (12.25 %). The company is the leading provider of polycrystalline silicon and other silicon-based products used in the semiconductor and solar industry.

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, was started in 2009. Total production capacity was 46 000 tonnes in 2011 and expanded to 56 000 tonnes in 2012. For 2012, a production of 28 000 tonnes is estimated.

4.4.5 Renewable Energy Corporation AS (Norway)

Renewable Energy Corporation AS (REC) (http://www.recgroup.com/) has a vision 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, REC 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 2005, REC 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). Production capacity at the end of 2012 was around 22 400 tonnes and according to the company, a total of 21 405 tonnes of polysilicon, of which 18 791 tonnes were electronic grade silicon, was produced in 2012.

4.4.6 SunEdison Inc. (USA)

SunEdison (http://sunedisonsilicon.com), formerly MEMC Electronic Materials Inc., has its headquarters in St Peters (Missouri), United States. It started operations in 1959 and the company's products are semiconductor-grade wafers, granular polysilicon, ultra-high-purity silane, trichlorosilane, silicon tetraflouride, 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 6 000 tonne factory in Merano, Italy, and in 2012 it reduced its capacity in Portland (Oregon), United States. The production capacity at the end of 2012 should have been of the order of 10 000 tonnes, while a production of about 12 000 tonnes is estimated.

SunEdison is developing solar power projects as well as a solar energy provider. At the end of 2012, the company had 73 MW under construction and 2.6 GW of projects in the pipeline.

4.4.7 Tokuyama Corporation (Japan)

Tokuyama (http://www.tokuyama.co.jp/) is a chemical company involved in the manufacturing of solar-grade silicon, the base material for solar cells. The company is one of the world's leading polysilicon manufacturers and produces roughly 16% of the global supply of electronics and solar-grade silicon. According to the company, Tokuyama had an annual production capacity of 5200 tonnes n 2008 and expanded this to 9200 tonnes in 2010. In February 2011, the company broke ground for a new 20000 tonne acility in Malaysia. The first phase with 6200 tonnes started a trial production in March 2013 and the second phase with 13800 tonnes should be fully operational in 2015. For 2012, a production of 7800 tonnes is estimated.

4.4.8 M.Setek Co. Ltd (Japan)

M.Setek is a subsidiary of Taiwan's AU Optronics. The company is a manufacturer of semiconductor equipment and monocrystalline silicon wafers. It has two plants in Japan (Sendai and Kouchi) and two in the China, Hebei Lang Fang 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. For 2012, a production capacity of 7000 tonnes was reported [Ikk 2013a]. Production was estimated to be 5600 tonnes in 2012.

4.4.9 Kumgang Korea Chemical Company (South Korea)

Kumgang Korea Chemical Company (KCC) (http://www.kccworld.co.kr/eng/) was established by a merger of Kumgang and the Korea Chemical Co. in 2000. In February 2008, KCC announced its investment in the polysilicon industry and began manufacturing high-purity polysilicon with its own technology at the pilot plant of the Daejuk factory in July of the same year. In February 2010, KCC started to mass-produce polysilicon, with an annual capacity of 6000 tonnes and increased it to 12100 tonnes in 2012 [Ikk 2013a]. Production is estimated to be 5400 tonnes in 2012.

4.4.10 Daqo New Energy Co., Ltd (China)

Daqo New Energy (http://www.dqsolar.com/) is a subsidiary company of the Daqo Group and was founded by Mega Stand International Ltd in January 2008. The company first built a high-purity polysilicon factory, with an annual output of 3300 tonnes in the first phase, in Wanzhou, China. 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 reached more than 4300 tonnes at the end of 2011. In the fourth quarter of 2012, expansion Phase 2 with 3000 tonnes was scheduled to come on line and expansion Phase 3 with another 3000 tonnes is scheduled for 2013. The company has invested in the downstream business, including wafers, cells, modules and projects. At the end of 2011, the company had a manufacturing capacity of 125 MW wafers and 100 MW modules. According to the company, it invested in solar cell production without specifying a capacity. In 2012, the company reported a polysilicon production of 3585 tonnes.

5. OUTLOOK

After a decade of continued increases in new investments in clean energy worldwide, 2012 ended with a decrease of 11 % compared to 2011, with investments totalling USD 269 billion (EUR 207 billion[20]), and including USD 30.5 billion (EUR 23.5 billion) corporate and government R&D spending [Blo 2013, Pew 2013]. Despite the overall decrease, some of the world's regions saw a significant increase in investments.

In 2012, clean energy markets outside the Group of 20 (G20) grew by more than 50 % to exceed USD 20 billion (EUR 15.4 billion), whereas investments in the G20 countries dropped by 16 % to USD 218 billion (EUR 167.7 billion). Despite the overall decline in investments, the decrease of renewable energy system prices more than compensated for this and allowed these investments to install a record of 88 GW of new clean energy generation capacity, bringing the total to 648 GW and capable of producing more than 1 500 TWh of electricity or 64 % of the electricity generated by nuclear power plants worldwide.

In contrast to Europe and the Americas, where new investments in renewable energy decreased, new investments continued to increase in Asia/Oceania and reached USD 101 billion (EUR 77.7 billion) in 2012. Europe took second place with USD 62.1 billion (EUR 47.8 billion), followed by the Americas with USD 50.3 billion (EUR 38.7 billion) [Pew 2013]. With a 20% increase, China became the largest investor in renewable energy with USD 65.1 billion (EUR 50.1 billion), followed by the USA with USD 35.6 billion (EUR 27.4 billion) and Germany with USD 22.8 billion (EUR 17.5 billion). The country with the biggest change in 2012 was South Africa, which moved into ninth place with investments totalling USD 5.5 billion (EUR 4.2 billion).

For the third year in a row, solar power attracted the largest amount of new investments in renewable energies. Despite a 9 % decline in solar energy investments, it attracted 57.7 % of all new renewable energy investments or USD 137.7 billion (EUR 105.9 billion) [Blo 2013a].

The PV industry has changed dramatically over the last few years. China has become the major manufacturing place for solar cells and modules, followed by Taiwan, Germany and Japan. Amongst the 20 biggest PV manufacturers in 2012, only three had production facilities in Europe, namely First Solar (USA, Germany, Malaysia), Hanwha Q CELLS (South Korea, Germany, Malaysia and China) and REC (Norway and Singapore). However, REC discontinued manufacturing in Norway and First Solar closed its factory in Germany at the end of 2012. After the acquisition of Q CELLS by Hanwha Solar, it remains to be seen what production capacity will remain in Germany in the long run.

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 just looking at the cell production does not give the whole picture of the complete PV value chain. Besides the information in this report 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) also have to be examined.

The implementation of the 100 000 roofs programme in Germany in 1990, and the Japanese long-term strategy set in 1994, with a 2010 horizon, marked the beginning of an extraordinary growth in the PV market. Before the start of the Japanese market implementation programme in 1997, annual growth rates of the PV markets were about 10 %, mainly driven by communication, industrial and stand-alone systems. Since 1990, PV production has increased by almost three magnitudes, from 46 MW to about 38.5 GW in 2012. This corresponds to a CAGR of a little more than 35 % over the last 22 years. Statistically documented cumulative installations worldwide accounted for almost

20) Exchange rate: EUR 1.00 = USD 1.30

100 GW in 2012. The interesting fact is, however, that cumulative production amounts to over 125 GW over the same time period. Even if we do not account for the roughly 8 to 10 GW difference between the reported production and installations in 2012, there is a considerable 15 GW capacity of solar modules which are statistically unaccounted for. Some of it may be in consumer applications, which do not contribute significantly to power generation, but the vast majority of it is probably used in stand-alone applications for communication purposes, cathodic protection, water pumping, streetlights, and traffic and garden lights, etc.

The temporary shortage in silicon feedstock, triggered by the high growth rates of the PV industry 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 for solar modules and polysilicon, has put enormous economic pressure on a large number of companies and is accelerating the consolidation of the industry. The benchmark was set by the Chinese Ministry of Industry and Information Technology, when it announced in February 2012 that it is aiming for an industry consolidation with polysilicon companies, having a polysilicon production capacity of at least 50 000 tonnes, and solar cell manufacturers with at least 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 and Japan.

Even with the ongoing economic difficulties, the number of new PV markets worldwide is increasing. This, as well as the overall rising energy prices and the pressure to stabilise the climate, 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 frame conditions vary and lead to a short-term downturn.

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 for fossil energy resources higher and higher. Already in 2007, a number of analysts were predicting that oil prices could well hit 100 USD/bbl by the end of that year or early 2008 [IHT 2007]. After the spike in oil prices in July 2008, when it was close to 150 USD/bbl, prices decreased due to the worldwide financial crisis and hit a low around 37 USD/bbl in December 2008. Since then, the oil price has rebounded and the IEA reported average prices for oil imports at around 110 USD/bbl since the second quarter of 2011, with a peak around 120 USD/bbl in March and April 2012.

The Energy Watch Group estimated that worldwide spending on combustibles, fuels and electricity was between USD 5 500 billion (EUR 4 231 billion) to USD 7 500 billion (EUR 5 769 billion) in 2008 [Ewg 2010]. Between 2007 and 2010, about USD 1 840 billion (EUR 1 415 billion) were spent on direct fossil fuel consumption subsidies and tax breaks, according to a joint report of 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 $480 billion in 2011 (0.7% of global GDP or 2% of total government revenues). The cost of subsidies is especially acute in 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 $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 2012, over USD 3 000 billion (EUR 2 300 billion) were spent on direct fossil fuel subsidies worldwide (this does not include global producer subsidies) [IEA 2011, 2012]. With 2007 to 2012 PV system prices, this subsidy would have been sufficient to install about 680 GW of PV systems worldwide. With the current residential system cost of around 2.2 USD/Wp (1.7 EUR/ Wp), the amount would be sufficient to install 1 360 GW of PV electricity systems.

After 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, like the permitting 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 second quarter of 2013, the average system price for residential systems was about 1.60 EUR/Wp (2.10 USD/Wp) in Germany, but between 4.5 and 5.1 USD/Wp (3.5 and 3.9 EUR/Wp) in California and Japan [Blo 2013b]. According to Bloomberg New Energy Finance (BNEF), one reason for the higher prices in California and Japan is the fact that the high 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 slowly. EPC quotes for large systems are already much lower and turnkey system prices as low as 1.0 EUR/Wp (1.3 USD/Wp) have been reported for projects to be finished in 2013 [Blo 2012].

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 21 July 2013, about 24 GW of solar power was on the German grid, covering more than 40% of the total electricity demand at noon. To effectively handle these high shares of renewable electricity, new technical and regulatory solutions have to be implemented in order not to run 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. A recent business analysis for electric vehicles by McKinsey showed that the current price of lithium-ion batteries in the range 500 to 600 USD/kWh (385 to 460 EUR/kWh) storage capacity could fall to 200 USD/kWh (155 EUR/kWh) storage capacity by 2020 [Hen 2012]. Lithium-ion batteries have an average of 5 000 cycles, which corresponds to a net kWh price of 0.10 to 0.12 USD/kWh (0.077 to 0.093 EUR/kWh) now and should fall to 0.04 USD/kWh (0.03 EUR/kWh) by 2020. With LCOE from PV systems reaching 0.12 to 0.14 USD/kWh (0.092 to 0.108 EUR/kWh) in the second quarter of 2013 [Blo 2013f], 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 construction on 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.

According to investment analysts and industry prognoses, solar energy will continue to grow at high rates in the coming years. The different PV industry associations, as well as Greenpeace, the European Renewable Energy Council (EREC) and the International Energy Agency, have developed new scenarios for the future growth of PV systems. Table 6 shows the different scenarios of the Greenpeace/EREC study, the IEA PV Technology Roadmap and the different 2011 and 2012 IEA World Energy Outlook scenarios. It is interesting to note that the 2015 capacity values of the Greenpeace reference scenario and the IEA 2011 scenarios (in red) were already exceeded in 2012. With forecasted new installations of between 129 and 150 GW in 2013, 2014 and 2015, even the Greenpeace revolution scenario no longer seems like fiction[Blo 2013b].

Table 6: Evolution of the cumulative solar electrical capacities until 2050 [Gre 2012, IEA 2010 IEA 2011a]

Year	2012 [GW]	2015 [GW]	2020 [GW]	2030 [GW]	2035 [GW]
Actual Installations	**100**				
Greenpeace[1] (reference scenario)		88	124	234	290
Greenpeace[1] ([r]evolution scenario)		234	674	1 764	2 420
IEA PV Technology Roadmap[2]		76	210	872	1,330
IEA New Policy Scenario 2011[3]		112	184	385	499
IEA New Policy Scenario 2012		153	266	491	602
IEA 450 ppm Scenario 2011[3]		70	220	625	901
IEA 450 ppm Scenario 2012[4]		150	303	720	966

1) 2035 values are extrapolated, as only 2030 and 2040 values are given
2) 2015 and 2035 values are extrapolated, as only 2010, 2020, 2030 and 2040 values are given
3) 2015 values are extrapolated, as only 2009 and 2020 values are given
4) 2015 value is extrapolated, as only the average growth rate from 2010 to 2035 and the 2020 value is 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 2012 Energy Technology Perspectives (ETP 2012) state that the total investment costs between 2010 and 2050 for achieving a low-carbon energy sector (2 ºC scenario, 2DS) would be UDS_{2010} 140 trillion (EUR 108 trillion) [IEA 2012a]. This would be USD_{2010} 36 trillion (EUR 27.8 trillion) more than what is needed under the assumption that controlling carbon emissions is not a priority (6 ºC scenario, 6DS). However, the estimated fuel savings of the low-carbon scenario are between USD_{2010} 97 trillion (EUR 74.6 trillion) and USD_{2010} 150 trillion (EUR 115 trillion) or 2.7 to 4.1 times the additional investment needed. This clearly indicates the huge societal benefit of a more aggressive climate change approach.

In the electricity sector, the investments for 6DS would amount to USD_{2010} 28.4 trillion (EUR 21.8 trillion) and about USD_{2010} 18 trillion (EUR 13.8 trillion) would be needed for new power generation plants. The base 2DS has an additional financial requirement of USD_{2010} 7.6 trillion (EUR 5.8 trillion), mostly in power generation capacity.

It is worthwhile mentioning that the high renewable 2DS scenario, with 71 % electricity from renewables, has additional investment costs of USD_{2010} 10.2 trillion (EUR7.8 trillion), but this is offset by fuel savings of around USD_{2010} 34 trillion (EUR 26.2 trillion) and far less than 30 years of the average annual subsidies paid to fossil energy between 2007 and 2012.

Due to the long lifetime of power plants (30 to 50 years), the decisions taken now will influence key socio-economic and ecological factors of our energy system in 2020 and beyond. As mentioned above, the ETP 2012 shows that fuel savings are 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 underway 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 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, PV markets will show accelerated growth rates. However, this development will influence the competitiveness of small and medium 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, is gradually changing into a more balanced 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 of the manufacturing industry and markets.

Over the last 10 years, not only have we observed a continuous rise in oil and energy prices, but also greater volatility. This highlights the vulnerability caused 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 see a continuous decrease in production costs for renewable energy technologies and the resulting LCOE, as a result of industry learning curves. Due to the fact that external energy costs, subsidies in conventional energies and price volatility risks are generally not taken into account, renewable energies and photovoltaics are still perceived as being more expensive in the market than conventional energy sources. Nevertheless, electricity production from PV solar systems has now already proved that it can be cheaper than residential consumer prices in a wide range of countries. In addition, renewable energies are, in contrast to conventional energy sources, the only ones to offer the prospect of a reduction in prices rather than an increase in the future.

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European Commission

EUR 26118 – Joint Research Centre – Institute for Energy and Transport

Title: PV Status Report 2013

Author(s): Dr. Arnulf Jäger-Waldau

Luxembourg: Publications Office of the European Union

2011 – 58 pp. – 29.7 x 21 cm

EUR – Scientific and Technical Research series – ISSN 1831-4155 (print), ISSN 1977-7086 (pdf)

ISBN 978-92-79-32719-3 (print)
ISBN 978-92-79-32718-6 (PDF)

DOI: 10.2790/93873 (print)
DOI : 10.2790/93822 (PDF)

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.

LB-XB-13-001-EN-C

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Publications Office

ISBN 978-92-79-32719-3