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Part 1

Arnulf Jäger-Waldau

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PV Status Report 2012

Research, Solar Cell Production and Market Implementation of Photovoltaics

September 2012

Part 1

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Preface

In June 2009, the European Directive on the "Promotion of the Use of Energy from Renewable Sources" went into force and does not only set mandatory targets for the Member States in 2020, but also gives a trajectory how to reach them. The aim of the Directive is to provide the necessary measures for Europe to reduce its greenhouse gas emissions by 20% in 2020, in order to support the world-wide stabilisation of the atmospheric greenhouse gases in the 450 to 550 ppm range.

In 2010, the IEA estimated in its Energy Technology Perspectives 2010, that the additional investment requirements in the power sector between 2010 and 2050, compared to the *"Baseline Scenario"* of $23.5 trillion (€18 trillion), would be $9.3 trillion (€7.15 trillion) for the *"Blue Map Scenario"* (450 ppm). At first sight, this looks like a lot of additional investment, but it is much less than the continuation of the fossil fuel subsidies. In 2010, the direct consumption subsidies in developing countries were $409 billion (€315 billion) and the support to fossil fuel in OECD countries added another $45 and 75 billion (€34.6 – 57.7 billion). Over 40 years this would sum up to almost $19 trillion (€14.6 trillion). Compared to these figures, subsidies to renewable energy are small, quoted with $66 billion (€50.8 billion), out of which $44 billion (€33.8 billion) went to renewable electricity in 2010.

At the end of 2011, the European Commission presented its Energy Roadmap 2050, and in its *Communication on Renewable Energy*, in June 2012, highlighted the need to decide on new post-2020 targets before the originally set timeframe in 2018. The discussion about renewable energy targets for 2030 is heating up, and the European Renewable Energy Council (EREC) already presented its request to set a 45% renewable energy target for the European Union for 2030.

Photovoltaics is a key technology option to realise the shift to a decarbonised energy supply. The solar resources in Europe and world-wide are abundant and cannot be monopolised by one country. Regardless for what reasons, and how fast the oil price and energy prices increase in the future, photovoltaics and other renewable energies are the only ones to offer a reduction of prices, rather than an increase in the future.

From 2008 to second quarter of 2012, residential PV electricity system prices have decreased by almost 60% in the most competitive markets, and in some markets, the cost of PV-generated electricity is already cheaper than residential electricity retail prices. Due to falling PV system prices and increasing electricity prices, the number of such markets is steadily increasing. The consequences of the nuclear accident which took place in Fukujima in March 2011, was a shift in energy investments toward more renewables and photovoltaic systems. In 2011, solar energy attracted 48.5% of all new renewable energy investments or $128 billion (€98.5 billion). Investments in distributed photovoltaic energy systems increased to over $71 billion (€54.6 billion).

In 2011, the photovoltaic industry production increased by almost 40% and reached a world-wide production volume of about 35 GWp of photovoltaic modules. Yearly growth rates over the last decade were on average between 40% and 90%, which makes photovoltaics one of the fastest growing industries at present.

The Eleventh Edition of the "PV Status Report" tries to give an overview about the current activities regarding Research, Manufacturing and Market Implementation. Over the last fifteen years, the photovoltaic industry has grown from a small group of companies and key players, into a global business where information gathering is getting more and more complex. Not every country and development is treated with the same attention, but this would go beyond the scope of this report. Any additional information would be highly welcome and will be used for the update of the report.

Ispra, September 2012

Arnulf Jäger-Waldau

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1. Introduction

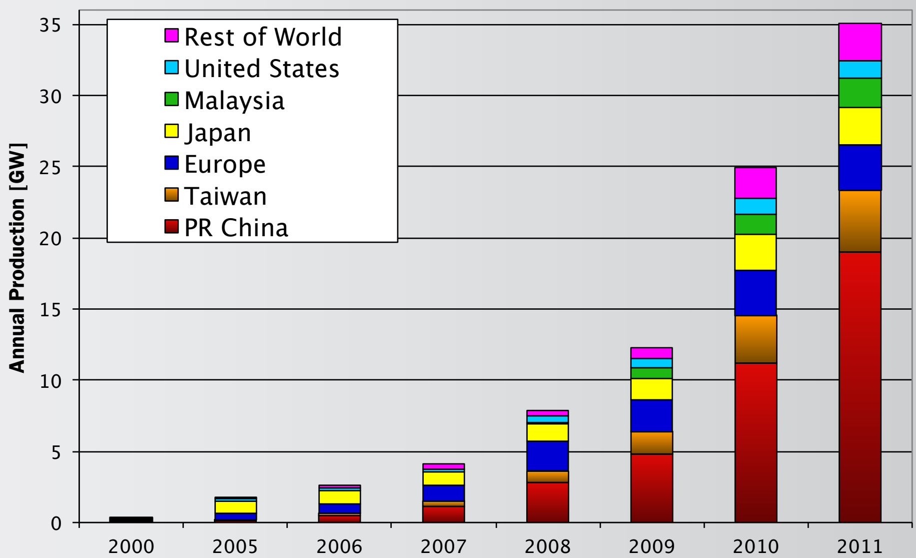
Production data for the global cell production[1] in 2011 vary between 30 GW and 37 GW. The significant uncertainty in this data is due to the highly competitive market environment, as well as the fact that some companies report shipment figures, while others report sales and again others report production figures. Another uncertainty is the fact that some companies sometimes produce less solar cells than solar modules, but the reporting does not always differentiate between the two. Therefore, some of the solar cell production can be counted double if they are attributed to the original cell manufacturer and then again to the company producing both cells and modules. In addition, the difficult economic conditions and increased competition led to a decreased willingness to report confidential company data. The year was characterised by a sluggish first half year and a boom in the fourth quarter of 2011.

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 35 GW (Fig. 1), representing an increase of 37% compared to 2010.

Since 2000, total PV production increased almost by two orders of magnitude, with annual growth rates between 40% and 90%. The most rapid growth in annual production over the last five years could be observed in Asia, where China and Taiwan together now account for more than 65% of world-wide production.

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

Fig. 1: World PV Cell/Module Production from 2000 to 2011
(data source: Photon International [Pho 2012], PV News [Pvn 2012] and own analysis)



Public-traded companies manufacturing solar products, or offering related services, have attracted a growing number of private and institutional investors. In 2011, world-wide new investments into the renewable energy and energy efficiency sectors increased to a new record of $263 billion (€202 billion[2]), including $25.8 billion (€19.8 billion) research and development spending [Pew 2012]. More than 85% or $225 billion (€173 billion) of these investments are non-governmental, non-research clean energy investments. These investments resulted in a record of 83.5 GW of new clean energy generation capacity, bringing the total to more than 565 GW or 50% more than the installed nuclear generating capacity world-wide.

For the second year in a row, solar power attracted the largest amount of new investments into renewable energies [Pew 2012]. The 44% increase in solar energy investments to $128 billion (€98.5 billion) offset a 15% decline in both wind and energy efficiency investments. Asset finance grew by 12% to $141 billion (€108 billion), investments in distributed photovoltaic projects grew 25% to $71.5 billion (€55 billion) and venture capital and private equity investments grew by 8.6% to reach $8.6 billion (€6.6 billion), whereas public and private research and development investments fell 18% to $26 billion (€20 billion) [Pew 2012].

Europe was still the leading region in terms of renewable energy investments (without research and development spending), totalling $87.7 billion (€67.5 billion), followed by Asia/Oceania with $75 billion (€57.7 billion) and the Americas with $63.1 billion (€48.5 billion) [Pew 2011]. However, renewable energy investments in the Asia/Oceania region again grew faster than in Europe, mainly through major investment increases in India, Japan and Indonesia.

At the end of 2011 about 73% or $141.6 billion (€108.9 billion) of the $194.3 billion (€149.5 billion) global "green stimulus" money from governments, aimed to help relieve the effect of the recession, had reached the markets [Pew 2012]. For 2012 another $35 billion (€26.9 billion) are expected.

The existing over-capacity in the solar industry has led to a continuous price pressure along the value chain and resulted in a reduction of spot market prices for polysilicon material, solar wafers and cells, as well as solar modules of 50% over the last two years [Blo 2012]. These rapid price reductions are putting all solar companies under enormous pressure and the access to fresh capital is key to survival. It is believed that this situation will continue for at least the next few years and put further pressure on the reduction of the average selling prices (ASP), even if the overall reductions will not be as large as in the last years. The continuation of the financial crisis added pressure as it resulted in higher government bond yields, and ASPs have to match to allow for higher project internal rate of returns (IRRs). On the other hand, the declining module and system prices already opened new markets, which offer perspectives for further growth of the industry – at least for those companies with the capability to expand and reduce their costs at the same pace.

Despite the problems of individual companies, business analysts are confident that the industry fundamentals, as a whole, remain strong and that the overall photovoltaics sector will continue to experience significant long-term growth. In July 2012, the IEA published, for the first time, a *Medium-Term Renewable Energy Market Report,* which forecasts a more than threefold increase of cumulative PV installations in 2017, compared with 2011 [IEA 2012].

Market predictions for the 2012 PV market vary between 28.4 GW in the Bloomberg conservative scenario [Blo 2012], 30 to 31 GW by Solarbuzz and IMS research [Sol 2012, Ims 2012], and 35.4 GW in the Bloomberg optimistic scenario [Blo 2012]. In the first half of 2012, global installations of PV electricity systems have exceeded 13 GW, with Germany (4.37 GW), Italy (1.8 GW) and USA (1.7 GW) as the leading markets.

Despite a number of bankruptcies and companies idling production lines, or even closing down their production permanently, the number of new entrants into the market is still high and massive capacity increases are underway, or announced, and if all of them are realised, the world-wide production capacity for solar cells would exceed 80 GW at the end of 2012. This indicates that even with the optimistic market growth expectations, the planned capacity increases are way above the market growth. The consequence is the continuation of the overall low utilisation rate and therefore, a continued price pressure in an over-supplied market. Such a development will accelerate the consolidation of the photovoltaics industry and spur even more mergers and acquisitions.

The current solar cell technologies are well established and provide a reliable product, with sufficient efficiency and energy output for at least 25 years of lifetime. This reliability, the increasing potential of electricity interruption from grid overloads, as well as the rise of electricity prices from conventional energy sources, add to the attractiveness of photovoltaic systems.

[2] Exchange rate: 1 € = 1.30 US$

About 85% of the current production uses wafer-based crystalline silicon technology. A major advantage of this technology is that complete production lines can be bought, installed and be up and producing within a relatively short time-frame. This predictable production start-up scenario constitutes a low-risk placement with calculable return on investments. However, the temporary shortage in silicon feedstock and the market entry of companies offering turn-key production lines for thin-film solar cells, led to a massive expansion of investments into thin-film capacities between 2005 and 2009. More than 200 companies are involved in the thin-film solar cell production process, ranging from R&D activities to major manufacturing plants.

Projected silicon production capacities available for solar in 2012 vary between 328,000 metric tons [Ihs 2012] and 410,330 metric tons [Ikk 2012]. The possible solar cell production will, in addition, depend on the material used per Wp. The current world-wide average is about 6 g/Wp.

Similar to other technology areas, new products will enter the market, enabling further cost reduction. 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 approx. 300. In order to maximise the benefits of CPV, the technology requires high Direct Normal Irradiation (DNI) and these areas have a limited geographical range – the "Sun Belt" of the Earth. The market share of CPV is still small, but an increasing number of companies are focusing on CPV. In 2011, about 60 MW of CPV were installed and market estimates for 2012 are varying in between the 10 to 70 MW range [Min 2012]. In addition, dye-cells are getting ready to enter the market as well. The development of these technologies is accelerated by the positive development of the PV market as a whole, but the competition for the right business case it becoming more fierce.

It can be concluded that in order to maintain the extremely high growth rate of the photovoltaic industry, different pathways have to be pursued at the same time:

- Further reduction of material consumption per silicon solar cell and Wp, e.g. higher efficiencies, thinner wafers, less wafering losses, etc.;

- Accelerated ramp-up and cost reduction of thin-film solar cell manufacturing;

- Accelerated CPV introduction into the market, as well as capacity growth rates above the normal trend;

- Development of new business models for the collection, sale and distribution of photovoltaic 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 a fair and guaranteed access to the electricity grid and market.

Further photovoltaic system cost reductions will depend not only on the technology improvements and scale-up benefits in solar cell and module production, but also on the ability to decrease the system component costs, as well as the whole installation, projecting, operation, permitting and financing costs.

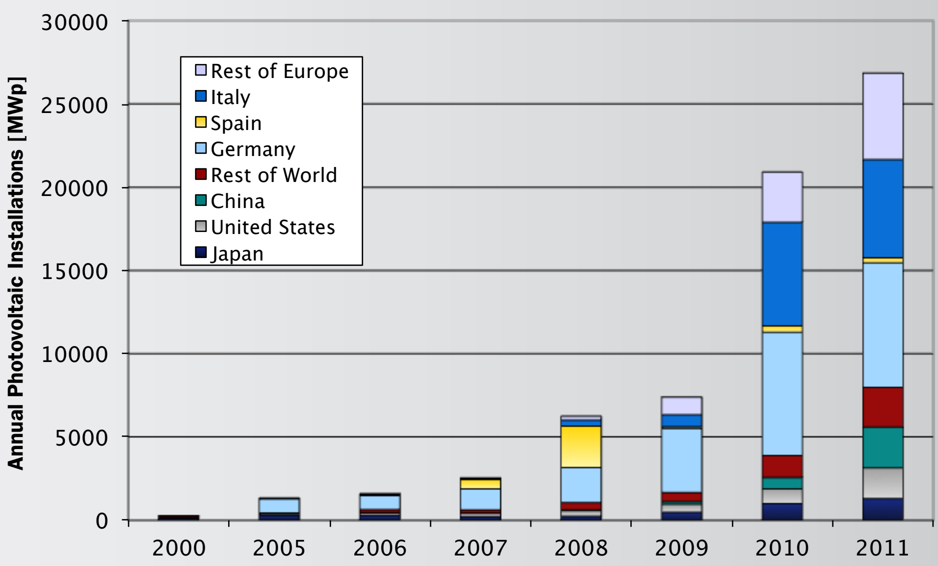
2. The Photovoltaic Market

After the world-wide photovoltaic market more than doubled in 2010, the market grew again by almost 30% in 2011, despite 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 probably already installed, but not yet connected. The continuation of the strong market in Italy and a year-end rush in Germany, where in the 4th quarter about 4 GW (3 GW in December alone) in conjunction with rapidly growing markets outside Europe in China and the USA resulted in a new installed capacity of almost 27 GW (Fig. 2). This represents mostly the grid-connected photovoltaic 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. A conservative estimate is that they account for approx. 400 to 800 MW (approx. 1-200 MW off-grid rural, approx. 1-200 MW communication/signals, approx. 100 MW off-grid commercial and approx. 1-200 MW consumer products). With a cumulative installed capacity of over 51 GW, the European Union is leading in PV installations with more than 70% of the total world-wide 70 GW of solar photovoltaic electricity generation capacity at the end of 2011.

2.1 Asia & Pacific Region

The Asia & Pacific Region continued its upward trend in photovoltaic electricity system installations. There are a number of reasons for this development, ranging from declining system prices, heightened awareness, favour-

Fig. 2: Annual Photovoltaic Installations from 2000 to 2011 (data source: EPIA [Epi 2012], Eurobserver [Sys 2012] and own analysis)



able 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 towards the promotion of solar energy and the creation of sustainable cities.

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

The Asian Development Bank (ADB) launched an Asian Solar Energy Initiative (ASEI) in 2010, which should lead to the installation of 3 GW of solar power by 2012 [ADB 2011]. In their report, ADB states: *Overall, ASEI aims to create a virtuous cycle of solar energy investments in the region, toward achieving grid parity, so that ADB developing member countries optimally benefit from this clean, inexhaustible energy resource.*

Three interlinked components will be used to realise the ASEI target:

Knowledge management: Development of a regional knowledge platform dedicated to solar energy in Asia and the Pacific.

Project development: ADB will provide $2.25 billion[3] (€1.73 billion) to finance the project development, which is expected to leverage an additional $6.75 billion (€5.19 billion) in solar power investments over the period.

Innovative finance instruments: A separate and targeted Asia Accelerated Solar Energy Development Fund has been set up to mitigate risks associated with solar energy. The fund will be used for a buy down programme to reduce the up-front costs of solar energy for final customers. ADB aims to raise $500 million (€385 million) and design innovative financing mechanisms in order to encourage commercial banks and the private sector to invest in solar energy technologies and projects.

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[3] Exchange rate: 1 € = 1.30 $

2.1.1 Australia

In 2011, 837 MW of new solar photovoltaic electricity systems were installed in Australia, bringing the cumulative installed capacity of grid-connected PV systems to 1.4 GW [Apv 2012]. PV electricity systems accounted for 36% of all new electricity generation capacity installed in 2011. Like in 2010, the market was dominated by grid connected systems which accounted for 91% of the new PV installations. The average PV system price for a grid connected system fell from 6 AUD/Wp (4.29 €/Wp[4]) in 2010 to 3.9 AUD/Wp (3 €/Wp[5]) in 2011 and the cost of PV generated electricity has reached the rate residents are paying in many parts of the country.

Most installations took advantage of the incentives under the Australian Government's Renewable Energy Target (RET) mechanisms and feed-in tariffs in some States or Territories. At the beginning of 2011, eight out of the eleven Australian Federal States and Territories had introduced eleven different kinds of feed-in tariff 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 are still available for new installations and additional changes are expected in the course of this year.

2.1.3 India

For 2011, market estimates for solar PV systems vary between 300 and 350 MW, and for the first time the most of these capacities were grid connected. The Indian Jawaharla Nehru National Solar Mission (JJNSM) was launched in January 2010, and it was hoped that it would give impetus to the grid-connected market. 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. In June 2012, grid connected PV capacity exceeded 1 GW with Gujarat leading the way with about 65% [Pvm 2012].

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. The short-term outlook up until 2013 was improved as well when the original 50 MW grid-connected PV system target in 2012 was changed to 1,000 MW for 2013.

2.1.4 Israel

Three years after the introduction of a feed-in tariff in 2008, Israel's grid-connected PV market saw about 130 MW of capacity newly connected in 2011. One of the main drives behind the development of solar energy is energy-security,

[4] Average Exchange rate 2010: 1 € = 1.40 AUD
[5] Average Exchange rate 2011: 1 € = 1.30 AUD

and it is planned to have about 1 GW of solar PV systems by the end of 2014. In August 2012, about 215 MW have been built and a further 300 MW approved [Blo 2012a]. The approved feed-in tariffs depend on the system size segment and have individual caps.

2.1.4 Japan

In 2011, the Japanese market experienced a moderate growth, increasing its volume to 1.3 GW, bringing the cumulative installed PV capacity to 4.9 GW. In the first half of 2012, about 840 MW of PV systems were installed, which is 50% more than in the same time in 2011.

The consequence of the accident at the Fukujima 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 plan targets to increase renewable power supply from the 2011 level of 11% to 25% to 35% by 2030.

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

In June 2012, METI finally issued the Ministerial Ordinances for the new feed-in tariffs for renewable energy sources. The tariff for commercial installations (total generated power) larger than 10kWp is ¥ 40 per kWh for 20 years and ¥ 42 per kWh for residential installations (surplus power) smaller than 10 kWp for 10 years starting from 1 July 2012 until 31 March 2013 [Ikk 2012].

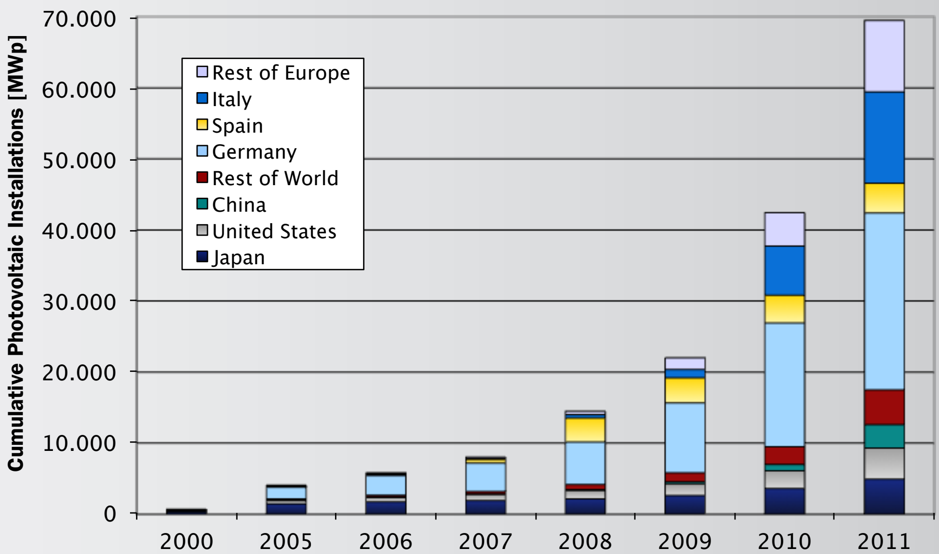
2.1.5 People's Republic of China

The 2011 Chinese PV market grew to 2.5 GW, bringing the cumulative installed capacity to about 3.3 GW [IEA 2012a]. This is a 400% growth compared to 2010, but still only 13% of the total Chinese photovoltaic production. A further increase can be expected due to the recent change of the target for 2015, which was increased to 21 GW by the National Energy Administration (NEA) [Reu 2012].

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% less carbon dioxide emissions and 16% less energy consumption unit of GDP. The total investment in the power sector under the 12th Five-Year Plan is expected to reach $803 billion (€618 billion), divided into $416 billion (€320 billion), or 52%, for power generation, and $386 billion (€ 298 billion) to construct 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 photovoltaic industry [MII 2012]. In this document the ministry outlined, that by 2015 it expects only to support "backbone" enterprises, which should produce a minimum of 50,000 MT polysilicon, or 5 GW of solar cell or module production. The plan also projects a cost reduction of electricity generated

Fig. 3: Cumulative Photovoltaic Installations from 2000 to 2011 (data source: EPIA [Epi 2012], Eurobserver [Sys 2012] and own analysis)



with PV systems to 0.8 CNY/kWh (0.098 €/kWh[6]) by 2015 and 0.06 CNY/kWh (0.074 €/kWh) by 2020.

In August 2012, the National Energy Administration (NEA) released the new renewable energy five-year plan for 2011 to 2015 [NEA 2012]. The new goal of NEA calls 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 be increased to 424 GW. Hydro-power is the main source, with 290 GW including 30 GW pumped storage, followed by wind with 100 GW, solar with 21 GW and biomass with 13 GW.

The plan estimates new investments in renewable energy of CNY 1.8 trillion (€222 billion) between 2011 and 2015. 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 (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 have been increased, as well, and are now a 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 investment of $64 billion (€49.2 billion) annually over the next two decades to implement an "energy-smart" growth strategy [WoB 2010]. However, the reductions in fuel costs through energy savings could largely pay for the additional investment costs according to the report. At a discount rate of 10%, the annual net present value (NPV) of the fuel cost savings from 2010 to 2030 would amount to $145 billion (€111.5 billion), which is about $70 billion (€53.8 billion) more than the annual NPV of the additional investment costs required.

2.1.6 South Korea

In 2011, about 157 MW of new PV systems were installed in South Korea, about the same as the year before, bringing the cumulative capacity to a total of 812 MW. Since January 2012, Korea's Renewable Portfolio Standard (RPS), officially replaced the feed-in tariffs. For 2012, a solar installation RPS target of 220 MW was set, which is well below the actual installed capacity and the gradual increases to 1.2 GW in 2015. The average spot market value of the Renewable Energy Certificates (RECs) for solar was about 165,000 KRW/MWh (116.5 €/MWh[7]). 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 Renewable Portfolio Standard (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, a move that is expected to bolster the development of Taiwan's green energy industry. The new law authorises the government to enhance incentives for the development of renewable energy via a variety of methods, including the acquisition mechanism, incentives for demonstration projects and the loosening of regulatory restrictions. The goal is to increase Taiwan's renewable energy generation capacity by 6.5 GW to a total of 10 GW within 20 years. In February 2012, the Ministry of Economic Affairs (MOEA),announced the new feed-in tariffs for 2012. To account for the continuing price reduction of systems, it was split into tariffs for January to June, and July to December. The reduction compared to 2011 for the first half of the year was between 5.5% and 8.3%, with an additional reduction of 7.8% to 10.3% for the tariffs in the second half.

Despite the favourable feed-in tariff, the total installed capacity at the end of 2011 was only between 90 and 100 MW, and the annual installation of about 70 MW was just 1.6% of the 4.3 GW solar cell production in Taiwan that year.

2.1.8 Thailand

Thailand enacted a 15-year Renewable Energy Development Plan (REDP) in early 2009, setting the target to increase the Renewable Energy share to 20% of final energy consumption of the country in 2022. Besides a range of tax incentives, solar photovoltaic electricity systems are eligible for a feed-in premium or "Adder" for a period of 10 years. The original 8 THB[8]/kWh (0.182 €/kWh) "Adder" (facilities in the three southern provinces, and those replacing diesel systems, are eligible for an additional 1.5 THB/kWh (0.034 €/kWh)) was reduced to 6.5 THB/kWh (0.148 €/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 the high over-subscription of the original target. At the end of 2011, out of the about 150 MW, including 30 MW, off-grid systems were installed. In June 2012, PV projects with about 500 to 600 MW were in their development phase and another 1.5 GW in the PPA application phase.

[6] Exchange Rate 2012: 1 € = 8.1 CNY

[7] Exchange Rate 1 € = 1,420 KRW

[8] Exchange Rate 1 € = 44 THB

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 the 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 and the Islamic Development Bank. Since the start of the programme, more than 1.4 million SHS, with an estimated capacity of 90 MW, have been installed in Bangladesh by June 2012 [WoB 2012]. According to media reports, every month about 50,000 additional households are added [Unb 2012].

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

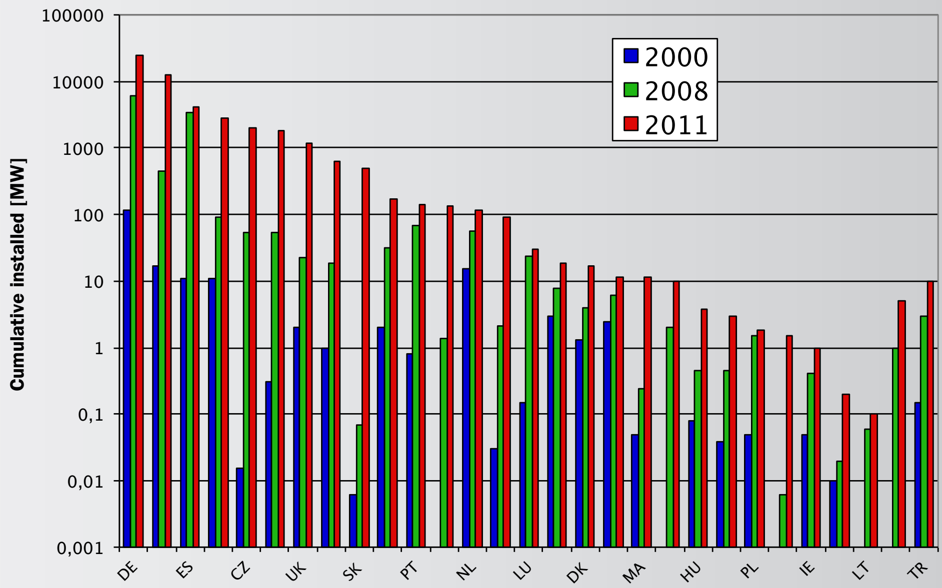
- **Indonesia:** The development of renewable energy is regulated in the context of the national energy policy by Presidential Regulation No. 5/2006 [RoI 2006]. The decree states that 11% of the national primary energy mix in 2025 should come from renewable energy sources. The target for solar PV is 1000 MW by 2025. At the end of 2011 about 20 MW of solar PV systems were installed, mainly for rural electrification purposes.

- **Malaysia:** The Malaysia Building Integrated Photovoltaic (BIPV) Technology Application Project was initiated in 2000 and at the end of 2009 a cumulative capacity of about 1 MW of grid-connected PV systems installed. The Malaysian Government officially launched their 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 feed-in tariffs were passed by the Malaysian Parliament. The 2012 tariffs were set by the Sustainable Energy Development Authority (SEDA) between 0.85 and 1.23 MRY/kWh (0.22 to 0.31 €/kWh[9]), depending on the system size. There are a number of add-ons depending on the use in buildings, or local content. For the next two years, an annual digression of the tariffs, by about 9% annually, is foreseen. As of August 2012, about 0.5 MW of PV systems, under the new FiT scheme, are already connected and another 166 MW have received approval, and are in various stages of project planning or installation.

  First Solar (USA), Q Cells (Germany) and Sunpower (USA) have set up manufacturing plants in Malaysia, with a total investment of RM 12 billion and more than 2 GW of production capacities. Once fully operational, these plants will provide 11,000 jobs and Malaysia will be the world's sixth largest producer of solar cells and modules.

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



[9] Exchange rate: 1 € = 3,90 MYR

- **The Philippines:** The Renewable Energy Law was passed in December 2008 [RoP 2008]. Under the Law, the Philippines has to 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.
  Early 2011, the country's Energy Regulator National Renewable Energy Board (NREB) has recommended a target of 100 MW of solar installations that will be constructed in the country over the next three years. A feed-in tariff of 17.95 PHP/kWh (0.299 €/kWh)[10] was suggested, to be paid from January 2012 onwards. For 2013 and 2014, an annual degression 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 €/kWh[11]) and confirmed the degression rate.
  At the end of 2011, about 12 MW of PV systems were installed, mainly off-grid.

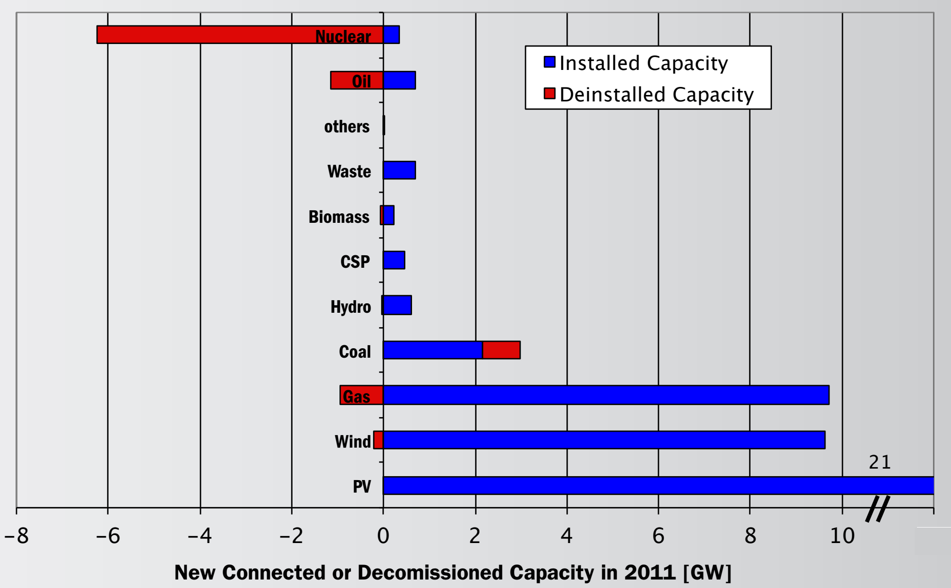
  SunPower had two cell manufacturing plants outside of Manila, but decided to close down Fab. No 1 early 2012. Fab. No 1 had a nameplate capacity of 125 MW and Fab. No 2 has another nameplate capacity of 575 MW.

- **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: 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.
  The Indo-Chinese Energy Company (IC Energy) broke ground for the construction of 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 on 14 May 2011. However, in June 2012, the company applied for the permission to delay the project with no new date set.
  In March 2011, First Solar broke ground on its four-line photovoltaic module manufacturing plant (250 MW) in the Dong Nam Industrial Park near Ho Chi Minh City, but decided early 2012 to put the facility up for sale.

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. Within one decade, the solar photovoltaic electricity generation capacity has increased 280 times from 185 MW in 2000 to 52 GW at the end of 2011 (Fig. 4) [Epi 2012, Sys 2012].

Fig. 5: New installed or decommissioned electricity generation capacity in Europe in 2011



[10] Exchange Rate 2011 1 € = 60 PHP
[11] Exchange Rate 2012 1 € = 53 PHP

A total of about 46.1 GW of new power capacity was connected in the EU last year and 7.8 GW were decommissioned, resulting in 38.3 GW of new net capacity (Fig. 5) [Ewe 2011, Sys 2011]. Photovoltaic electricity generation capacity accounted for 21.5 GW[12], or 56% of the new net capacity. In terms of new net capacity, wind power moved to the second place with 9.4 GW (25%), followed by 8.8 GW (23%) gas-fired power stations; 3.1 GW (8%) MW coal-fired power stations; 590 MW (1.5%) hydro, 470 MW (1.2%) CSP, 170 MW (> 1%) biomass; and 70 MW (> 1%) waste. The net installation capacity for oil-fired and nuclear power plants was negative, with a decrease of 447 MW and 5.9 GW respectively. The renewable share of new power installations was more than 65% and more than 76% of new net capacity in 2011.

In the following sub-chapters, the market development in some of the EU Member States, as well as Switzerland and Turkey, is described.

2.2.1 Belgium

Belgium showed another strong market performance year in 2011, with new photovoltaic system installations of 775 MW bringing the cumulative installed capacity to 1812 MW. However, most of the installations were done in Flanders, where, since 1 January 2006, Green Certificates exist for 20 years. In 2011, the value of the certificates decreased from 0.33 €/kWh (January to June) to 0.30 €/kWh (July to September) and 0.27 €/kWh (October to December). For 2012, the price decreases every four months by two Eurocents. In Wallonia, the Green Certificates have a guaranteed minimum price between 0.15 – 0.462 €/kWh, depending on the size of the systems and region (Wallonia 15 years).

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. Up until the end of July 2012, about 600 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 1 June 2012, new feed-in tariffs went into force, which correspond to a 34 to 54% reduction, depending on the system type. In July 2012, the Bulgarian Energy Regulator (SEWRC) proposed a further reduction, ranging between 5 and 35%.

2.2.3 France

In 2011, 1.63 GW of PV systems were connected to the grid in France, with a significant part of the systems already installed in 2010. This led to an increase of the cumulative installed capacity to 2.83 GW, including about 300 MW in the French Overseas Departments. Smaller decentralised systems are about 2.3 GW and larger solar farms are around 0.5 GW..

This rapid growth led to a revision of the feed-in scheme in February 2011, setting a cap of 500 MW for 2011 and 800 MW for 2012 [MEI 2011]. The 2011 tariff levels only applied to rooftop systems up to 100 kW in size. In addition, those installations were divided into three different categories: residential; education or health; and other buildings with different feed-in tariffs, depending on the size and type of installation. The tariffs for these installations ranged between 0.2883 €/kWh and 0.46 €/kWh. All other installations up to 12 MW were just eligible for a tariff of 0.12 €/kWh. The feed-in tariffs decreased by 10% on 1 January 2012 and a second decrease ranging between 2.6 and 9.5%, depending on the type of installation took place on 1 April. At the moment, France has three different support schemes for PV. For systems up to 100 kWp, there is the feed-in tariff, for rooftop systems between 100 and 250 kWp a "simplified" call for tender with a 300 MW cap for 2012 and for systems larger than 250 kWp (large rooftop and ground mount systems) the "ordinary" call for tender with a 450 MW cap.

Between March 2011 and March 2012, the regional distribution companies received applications worth 640 MW for new photovoltaic installations up to 100 kW in size, according to the French Energy Regulator CRE (Commission de Regulation de l'Energie). This was more than three times the target the government announced in 2011 for that market segment.

2.2.4 Germany

Germany had even a slight increase compared to 2010, from 7.4 GW to 7.5 GW [Bun 2012]. 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 feed-in tariff for electricity generated from solar photovoltaic 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 the correspond-

[12] The new connected PV capacity in 2011 includes those PV plants, which were already built in 2010, but not yet connected to the grid (mainly in Italy). Therefore, there is a difference of about 3 GW between the installation figures and the connection figures.

ing price reductions. Due to the fact that until 2008 only estimates of the installed capacity existed, a plant registrar was introduced from 1 January 2009 on.

The German market had a strong performance throughout the year with an extraordinary peak in December, when almost 3 GW were installed just before the scheduled tariff reduction of 15% on 1 January 2012. Compared to 2009, the feed-in tariffs have been reduced by 43 to 46% depending on the system size and classification. In August 2012 the Bundesnetzagentur (German Federal Network Agency) announced that almost 4.4 GW of new systems had been installed in the first half of 2012, bringing the total capacity to 29.2 GW.

2.2.5 Greece

Greece introduced a new feed-in tariff scheme on 15 January 2009. The tariffs remained unchanged until August 2010 and are guaranteed for 20 years. However, if a grid-connection agreement was signed before that date, the unchanged FIT was applied if the system is finalised within the next 18 months. For small rooftop PV systems, an additional programme was introduced in Greece on 4 June 2009. This programme covers rooftop PV systems up to 10 kWp (both for residential users and small companies). In 2011, the tariffs for PV systems, with the exception of small rooftop systems (<10 kWp) decreased in February by 5% and August by 6%. Despite the severe financial crisis, it is remarkable that 426 MW of new installations were carried out, bringing the total capacity to about 631MW in 2011. In view of the reduced system prices, the feed-in tariff for 2012 was lowered in February by 11% for small rooftop systems and 20% for all others. The changes in August were more drastic, with a tariff reduction of almost 50% to 0.25 €/kWh for small rooftop systems, 31% to 0.225€/kWp for systems up to 100 kWp and 28% to 0.18€/kWh for systems larger than 100 kWp.

2.2.6 Italy

Italy connected most new PV capacity with 9.1 GW, but this includes about 3.2 GW of PV systems, which were reported under the second "conto energia" and probably already installed, but not yet connected in 2010. In terms of new installations, Italy added a capacity of about 5.9 GW, bringing cumulative installed capacity to 12.8 GW at the end of 2011 [Ges 2012]. At the End of August 2012, the total connected PV capacity has surpassed 14.9 GW [Gse 2012a].

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 of the tariffs, and the annual expenditure ceiling for new installations has been increased from €500 million to €700 million. The 2012 ceiling is € 6.7 billion, but at the end of August already €6.2 to 6.3 billion have been allocated. In addition, a new requirement to register systems larger than 12 kWp was introduced. The new tariffs, valid from 27 August 2012, are between 13 and 21% lower than in the first half of the year and between 6 and 13% more than the reduction foreseen back in 2011.

2.2.7 Slovakia

In 2011, Slovakia experienced a rapid growth of PV system installations, with a more than doubling of the annual installations to 314 MW, mainly ground mounted systems. Cumulative installed capacity was 488 MW at the end of 2011. This is already three times the original 160 MW capacity target for 2020, published in the National Renewable Energy Action Plan in 2010. From February 2011, the support was limited to applications for systems smaller than 100 kW and after a reduction of the feed-in tariff by 35% mid 2011, the tariff has been reduced by 25% from 1 January 2012 on.

2.2.8 Spain

Spain is still third in Europe regarding 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 2012]. This was more than twice the expected capacity and was due to an exceptional race to install systems before the Spanish Government introduced a cap of 500 MW on the yearly installations in the autumn of 2008. A revised Decree (Royal Decree 1758/2008) set considerably lower feed-in tariffs 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 new installed capacity of about 20 MW in 2009, 370 MW in 2010 and 350 MW in 2011.

In May 2012, electricity generated with solar PV systems accounted for 4.5% of Spain's total electricity demand, according to the grid operator Red Eléctrica de Espana.

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 the fact that Spain's energy system has over time amassed a €25 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), the government allowed them to create a scheme like a deferral account whereby they could recover shortfalls in any individual year from revenues generated in subsequent years.

Already in January 2007, the European Commission 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 €3.8 billion in the Spanish electricity system which amounted to almost €9 billion in 2007, a time when payments under the special regime for renewable energy were still limited.

2.2.9 Switzerland

In 2011 100 MW of PV systems have been installed in Switzerland, almost doubling the total capacity to 211 MW. In addition, there is a waiting list with a total capacity of about 460 MW. In view of the decreasing PV system prices, two feed-in tariff reductions were scheduled in Switzerland. The first took place on 1 March 2012, with a 15 to 18% reduction and another 8 to 10% reduction is scheduled for 1 October 2012.

2.2.10 United Kingdom

The United Kingdom introduced a new feed-in tariff scheme in 2010, which led to the installation of approximately 55 MW, bringing the cumulative installed capacity to about 85 MW. The announcement of a fast-track review of large scale projects by the Department of Energy & Climate Change (DECC) in February 2012, led to a rush to complete those projects in the first half of 2011 [DEC 2011]. For systems larger than 50 kWp, the tariffs were reduced by 42% up to 72%. 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 in April were 44 to 54% for systems smaller than 50 kWp and 0 to 32% for systems above 50 kWp. For 1 November 2012, a further reduction of 3.5% for systems smaller 50 kWp is foreseen, whereas no reduction will be done for larger systems, due to the fact that almost no such systems have been installed between May and July 2012.

1.2.11 Other European Countries and Turkey

After two years with high growth rates, the PV market in the **Czech Republic** stalled due to a number of legislative changes which took place in the second half of 2010. They resulted in lower feed-in tariffs, the phase-out of ground-mounted PV systems from 1 March 2011 onwards and the introduction of a retroactive tax on benefits generated by PV installations. Despite the fact that the grid freeze had been lifted at the beginning of 2012, CEPS, the high grid voltage operator imposed a limit of 65 MW for new solar and wind installations, with a case-by case assessment of the individual projects.

Despite high solar radiation, solar photovoltaic system installation in **Portugal** has only grown very slowly and reached a cumulative capacity of 130 MW at the end of 2010.

In **Turkey** during March 2010, the Energy Ministry unveiled its 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 a Renewable Energy Legislation which defines new guidelines for feed-in tariffs. The feed-in tariff is 0.133 $/kWh (0.10 €/kWh) for owners commissioning a PV system before the end of 2015. If components 'Made in Turkey' are used, the tariff will increase by up to $0.067 (€0.052), depending on the material mix. Feed-in tariffs apply to all types of PV installations, but large PV power plants will receive subsidies up to a maximum size of 600 MWp.
At the beginning of 2012, about 10 MW of PV systems were installed, with a target of 3 GW set for 2023.

Ukraine saw an impressive growth, with almost 200 MW, thanks to the development of two very large power plants developed by one company. In July 2012, the Ukrainian Parliament had the first reading of a bill to simplify the access of households to the feed-in scheme. At the same time, it proposed a reduction in the feed-in tariff between 16 and 27%, depending on the kind of installation.

2.3 Africa

Despite the vast solar resources and the fact that there are areas in Africa where solar potential can be considered very interesting, with the same photovoltaic panel ready to produce twice as much electricity in Africa as in Central Europe on average, only limited use of solar photovoltaic electricity generation is made. The main application for PV systems in Africa are 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.

Capo Verde's Renewable Energy Plan (2010 to 2020) aims to increase the use of renewable energy to 50% in 2020. The policy to achieve this is to use PPA. **Law n1/2011** establishes the regulations regarding the 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 the self production at user level. It creates the micro-generation regime and regulates rural electrification projects and states the tax exemption of all imported RE equipment. At the end of 2011, 7.5 MW of centralised grid-connected PV systems were installed. In addition, there are a number of smaller off-grid and grid-connected systems. To realise the 2020 50% Renewable energy target, about 340 MW of PV systems are required.

In 2008, **Kenya** introduced feed-in tariffs for electricity from renewable energy sources, but solar was only included in the revision dated 2010 [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.

The **Kingdom of Morocco's** solar plan was introduced in November 2009, with the aim of establishing 2,000MW 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 openly compete. Already in 2007, the National Office of Electricity (ONE) announced a smaller programme for grid-connected distributed solar PV electricity, targeting 150 MW of solar PV power. Various rural electrification programmes using PV systems have been ongoing for a long time. At the end of 2011, Morocco had about 20 MW of PV systems installed, mainly under the Global Rural Electrification Programme (PERG) Framework and about 1 to 2 MW grid-connected systems.

South Africa has a fast 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]. The South African Renewables Initiative, under discussion in 2012, calls for 13.2 GW of PV systems installed by 2025. However, the projected installation costs of $10 billion (€7.7 billion) for 2 GW between the time-frame of 2013 to 2017, are extremely high, considering that on average the PV Project Apex was between $1.6 and 1.7 million (€1.23 to 1.3 million) per MW in the second quarter of 2012 [Blo 2012b]. In 2011, the Renewable Energy Independent Power Producer Procurement Programme (IPP) was set up with five biddings (one in 2011, two in 2012 and two in 2013) planned until 2013. The overall target is 3.725 GW and the one for solar photovoltaic is 1.45 GW. In the first two bidding rounds 1,048 MW of solar PV projects were already allocated to the preferred bidders. The average bid price changed between the first round (closure date: 4 November 2011) from 2.65 ZAR/kWh (0.252 €/kWh) to 1.65 ZAR/kWh (0.157 €/kWh) in the second round (closure date: 5 March 2012). However, it is still unclear when those projects will be connected to the grid. At the end of 2011, about 40 to 50 MW of PV systems were installed in South Africa.

2.4 Americas

2.4.1 Canada

In 2011, Canada almost doubled its cumulative installed PV capacity to about 570 MW, with 289 MW new installed systems. This development was driven by the introduction of a feed-in tariff in the Province of Ontario, enabled by the *"Bill 150, Green Energy and Green Economy Act, 2009"*. Ontario accounted for over 90% of all new installations. On the Federal level, only an accelerated capital cost allowance exists under the Income Tax Regulations. On a Province level, nine Canadian Provinces have *Net Metering Rules,* with solar photovoltaic 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 feed-in tariffs were set in 2009, depending on the system size and type and were reduced in various steps between 21 and 32%. On 5 April they were set as follows:

- Rooftop ≤ 10 kW
  54.9 ¢/kWh (0.422 €/kWh[13])
- Rooftop > 10 kW ≤ 100 kW
  54.8 ¢/kWh (0.422 €/kWh)
- Rooftop > 100 kW ≤ 500 kW
  53.9 ¢/kWh (0.415 €/kWh)
- Rooftop > 500 kW
  48.7 ¢/kWh (0.375 €/kWh)
- Ground-mounted[14] ≤ 10 kW
  44.5 ¢/kWh (0.34.2 €/kWh)
- Ground-mounted > 10 kW ≤ 500 kW
  38.8 ¢/kWh (0.298 €/kWh)
- Ground-mounted > 500 kW
  35.0 ¢/kWh (0.269 €/kWh)
- Ground-mounted* >10 kW ≤ 10 MW
  34.7 ¢/kWh (0.267 €/kWh)

The feed-in tariff scheme has a number of special rules, ranging from eligibility criteria, which limit the installation of ground-mounted PV systems on high-yield agricultural land to domestic content requirements and additional "price adders" for Aboriginal and community-based projects. Details can be found in the Feed-in Tariff Programme of the Ontario Power Authority [Ont 2012].

2.4.2 United States of America

With over 1.8 GW of newly installed PV capacity, the USA reached a cumulative PV capacity of almost 4.4 GW at the end of 2011. Utility PV installations again more than tripled, compared to 2010 and reached 754 MW in 2011. The top ten States - California, New Jersey, Arizona, New Mexico, Colorado, Pennsylvania, New York, North Carolina, Texas and Nevada, accounted for more than 87% of the US PV market [Sei 2012].

PV projects with Power Purchase Agreements (PPAs), with a total capacity of 9 GW, are already under contract and to be completed by 2016. Over 3 GW of these projects are already financed and under construction [Sei 2012]. If one adds the over 30 GW of projects in an earlier planning stage, which are actively seeking permits, interconnection agreements, PPAs and finance, the pipeline stands at 39 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, about 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. All the different support schemes are described therein and it is highly recommended to visit the DSIRE web-site www.dsireusa.org/ and the corresponding interactive tables and maps for details.

2.4.3 Emerging markets

In 2006, **Argentina** passed its Electric Energy Law which established that 8% of the 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. At the end of 2011, about 10 MW of PV systems were installed. According to the renewable energy country attractiveness indicator, the Argentinean Government has set a 3.3 GW target for PV installations by 2020 [Ern 2011].

At the end of 2011, **Brazil** had about 20 MW 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 install small distributed generation capacity. The rule applies to generators that use subsidised sources of energy (hydro, solar, biomass, cogeneration and wind). In its mid-term market report, the IEA forecasts a cumulative installed PV capacity of about 100 MW in 2012 and 900 MW by 2017 [IEA 2012].

In February 2012, the President of **Chile**, President Piñera, announced a strategic energy plan how to reach 20% of non-conventional renewable energy by 2020. Legislation to reach this 20% renewable energy targets is currently under consideration. In the first quarter of 2012, the first MW size PV system was installed in the northern Atacam desert. Chile's Environmental Assessment Service (SEA) has approved four solar photovoltaic projects, with a total of 506.5 MW in the Antofagasta region, on 20 August 2012. SEA approved the 76.7 MW and 69.8 MW Laberinto Este and Oeste, 180 MW Encuentro Solar and 180 MW Crucero Solar projects.

Already in 2007, the **Dominican Republic** passed a law promoting the use of renewable energy and set a target of 25% renewable energy share in 2025 [GoD 2007]. At that time about 1 to 2 MW of solar PV systems were installed

[13] Exchange Rate 1 € = 1.30 CAD
[14] Eligible for Aboriginal or community adder

in rural areas, which increased to over 5 MW in 2011. In 2011, when 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 (200 kW) of the project became operational in July 2012 and the whole solar farm should be connected to the grid early 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 foresees a decrease in Greenhouse Gas (GhG) 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 2011, about 37 MW of PV systems were installed according to the IEA PVPS [IEA 2012c]. According to media reports, investments in photovoltaic panel installations have increased by 150%, from $20 to $50 million (€15.4 to 38.5 million) from 2010 to 2011.

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 Control Agency 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, which should start operation before the end of 2012. A second bidding round was held in 2011, with a quota of 24 MW for PV.

3. The Photovoltaic Industry

In 2011, the photovoltaic world market grew by more than 35% in terms of **production** to about 35 GW. The market for installed systems grew by almost 30% and values between 26 and 28 GW were reported by various consultancies and institutions. This mainly represents the grid-connected photovoltaic market. To what extent the off-grid and consumer-product markets are included is unclear. The difference of roughly 7 to 9 GW has therefore to be explained as a combination of unaccounted off-grid installations (approx. 1-200 MW off-grid rural, approx. 1-200 MW communication/signals, approx. 100 MW off-grid commercial), consumer products (ca. 1-200 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, add to the uncertainty. An additional uncertainty is the fact that some companies produce sometimes less 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 double, first at the cell manufacturer and second 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 growth of the production, as well as an increasing installation market.

The announced production capacities, based on a survey of more than 350 companies world-wide increased, even with difficult economic conditions. Despite the fact that about three dozen companies declared bankruptcy, stopped production or announced a scale-back or cancellation of their expansion plans for the time being, the number of new entrants into the field, including some large semiconductor or energy-related companies overcompensated this. At least on paper the expected production capacities are still increasing. Only published announcements of the respective companies and no third source info were used. The cut-off date of the info used was August 2012.

Please note that production capacities are often calculated with different operation parameters such as number of shifts, operating hours per year, etc. In addition, the capacity increase announcements do not always specify when the capacity will be fully ramped up and operational. This method has of course the setback that a) not all companies announce their capacity increases in advance and b) that in times of financial tightening, the announcements of the scale-back of expansion plans are often delayed, in order not to upset financial markets. Therefore, the capacity figures just give a trend, but do not represent final numbers.

If all these ambitious plans can be realised by 2015, China will have about 61.1% of the world-wide production capacity of 119 GW, followed by Taiwan (14.3%), Europe and Japan (5.5%) (Fig. 6).

All these ambitious plans to increase production capacities at such a rapid pace, depend on the expectations that markets will grow accordingly. This, however, is the biggest uncertainty, as the market estimates for 2012 vary between 28 GW and 35 GW. In addition, most markets are still dependent on public support in the form of feed-in tariffs, investment subsidies or tax-breaks.

Already now, electricity production from photovoltaic solar systems has shown that it can be cheaper than peak prices in the electricity exchange. In the second quarter of 2012, the German average price index, for rooftop systems up to 100 kWp, was given with €1,776 per kWp, without tax or just 35% of the price six years ago [Bsw 2012]. With such investment costs, the electricity generation costs are already at the level of residential electricity prices in some countries, depending on the actual electricity price and the local solar radiation level. But only if markets and competition continue to grow, prices of the photovoltaic systems will continue to decrease world-wide and make electricity from PV systems for consumers even cheaper than from conventional sources. Further cost reduction of photovoltaic electricity now depends no longer only on the photovoltaic system components itself, but increasingly on the integration costs into the existing infrastructure. Therefore, to make PV-generated electricity a major source of the world-wide electricity supply for the next decade, more effort has to be focused on optimising the non-PV costs and public support, especially on regulatory measures.

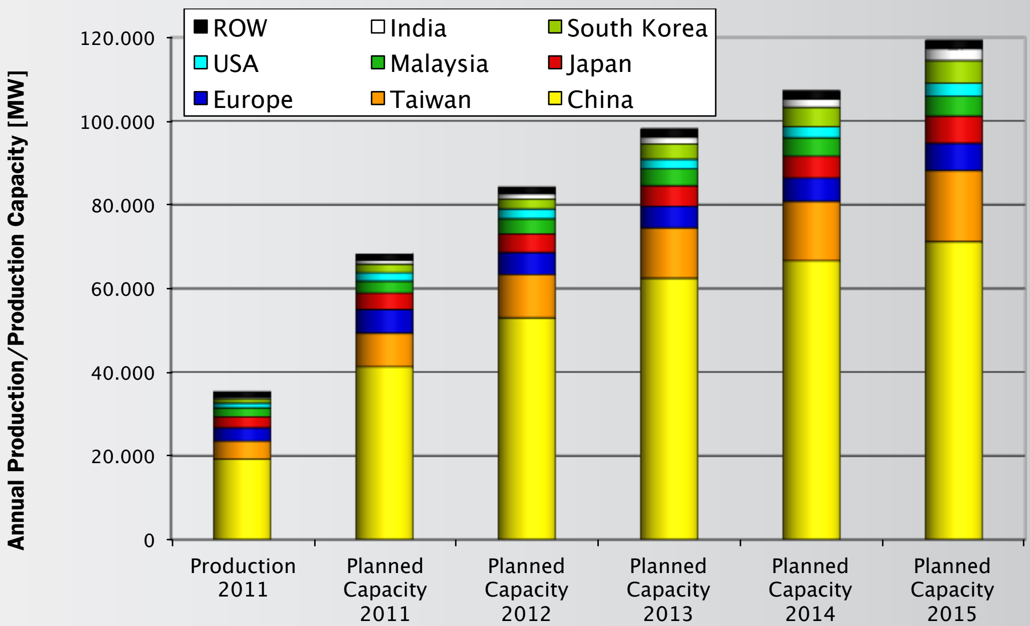
3.1 Technology Mix

As silicon prices fell drastically after the temporary silicon shortage, wafer-based silicon solar cells decreased their cost very rapidly and are still the main technology with around 85% market shares in 2011. Commercial module efficiencies are within a wide range between 12 and 20%, with monocrystalline modules between 14% – 20%, and polycrystalline modules between 12% – 17%. The massive manufacturing capacity increases for both technologies were followed by the necessary capacity expansions for polysilicon raw material.

In 2005, for the first time, production of thin-film solar modules reached more than 100 MW per annum. Between 2005 and 2009, the ***Compound Annual Growth Rate*** (CAGR) of thin-film solar module production was beyond that of the overall industry, increasing the market share of thin-film products from 6% in 2005 to 10% in 2007 and 16 – 20% in 2009. Since then, the thin film share is decreasing slowly as the ramp up of new production lines did not follow that of wafer-based silicon.

More than 200 companies are involved in thin-film solar cell activities, ranging from basic R&D activities to major manufacturing activities and over 120 of them have announced the start or increase of production. The first

Fig. 6: World-wide PV Production 2011 with future planned production capacity increases



100 MW thin-film factories became operational in 2007, followed by the first 1 GW factory in 2010. If all expansion plans are realised in time, thin-film production capacity could be 13 GW, or 15% of the total 80 GW in 2012, and 23 GW, or 19%, in 2015 of a total of 119 GW (Fig. 7).

One should bear in mind that less than 20 companies of the over 120 companies, with announced production plans, have produced thin-film modules of 50 MW, or more in 2011. Another 20 companies filed for insolvency, or announced the termination of their thin-film operations in the last 12 months.

The majority of companies is silicon-based and use either amorphous silicon or an amorphous/microcrystalline silicon structure, followed by companies using Cu(In,Ga)(Se,S)2 as absorber material for their thin-film solar modules, whereas only a few companies use CdTe or dye and other materials.

Concentrating Photovoltaics (CPV) is an emerging technology which is growing at a very high pace, although from a low starting point. About 50 companies are active in the field of CPV development and almost 60% of them were founded in the last six years. Over half of the companies are located either in the United States of America (primarily in California) and Europe (primarily in Spain).

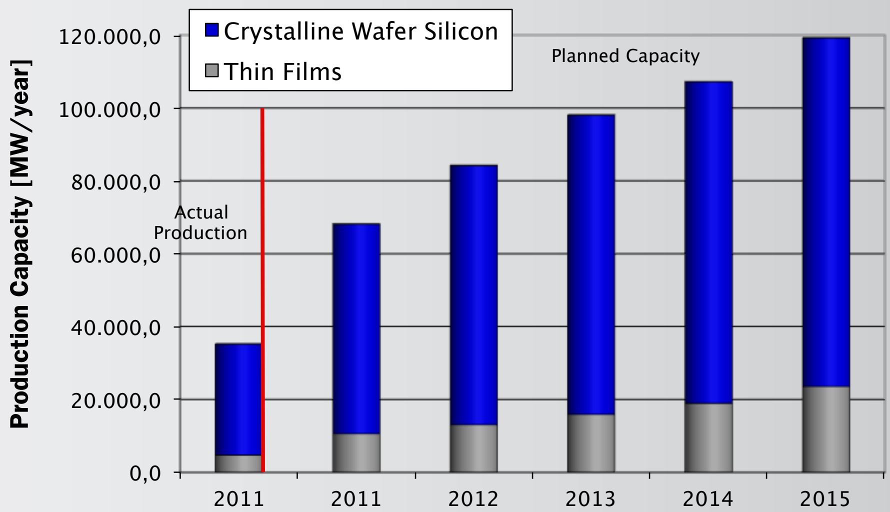
Within CPV there is a differentiation according to the concentration factors[15] and whether the system uses a dish (Dish CPV) or lenses (Lens CPV). The main parts of a CPV system are the cells, the optical elements and the tracking devices. The recent growth in CPV is based on significant improvements in all of 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 a 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, which can count on economy of scale.

With market estimates for 2011 in the 60 MW range, and 90 MW under construction in May 2012, the market share of CPV is still small, but analysts forecast an increase to more than 500 MW globally by 2015.

The existing photovoltaic 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. The variety of technologies is an insurance against a roadblock for the implementation of solar photovoltaic electricity, if material limitations or technical obstacles restrict the further growth or development of a single technology pathway.

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

Fig. 7: Annual PV Production capacities of Thin-Film and Crystalline Silicon based solar modules.



3.2 Solar Cell Production[16] Companies

World-wide, more than 350 companies produce solar cells. The solar cell industry over the last decade was very dynamic, but the changes which have been happening since 2011 allow only for a snapshot picture of the current situation, which might have changed a few weeks later already. Despite the fact that a few dozen of them 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 chapter gives a short description of the 20 largest companies, in terms of actual production/shipments in 2011. More information about additional solar cell companies and details can be found in various market studies and in the country chapters of this report. The capacity, production or shipment data are from the annual reports or financial statements of the respective companies or the cited references.

3.2.1 Suntech Power Co. Ltd. (PRC)
Suntech Power Co. Ltd. (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 photovoltaic cells, modules and systems. For 2011, Suntech reported sales of 2,066 MW and shipments of 2,096 MW, taking the top rank amongst the solar cell manufacturers. The annual production capacity of Suntech Power was increased to 2.4 GW by the end of 2011, and the company plans not to expand its capacity in 2012.

3.2.2 First Solar LLC. (USA/Germany/Malaysia)
First Solar LLC (www.firstsolar.com) is one of the few companies world-wide to produce CdTe-thin-film modules. The company has currently three manufacturing sites in Perrysburg (USA), Frankfurt/Oder (Germany) and in Kulim (Malaysia), which had a combined capacity of 2.376 GW at the end of 2011. The second Frankfurt/Oder plant, doubling 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 2011, the company produced 1.98 GW. In the second quarter of 2012, the company reported production costs of 0.72 $/Wp (0.554 €/Wp), including restructuring, underutilisation and other non-manufacturing costs of 0.19 $/Wp (0.146 €/Wp).
In April 2021 the company announced a major restructuring to respond to the changing market conditions [Fir 2012]. The company announced to close the factory in Frankfurt/Oder, Germany, and idle four production lines in Kulim. In addition, it put the factory in Meza (AZ), USA on hold, and is selling the already built factory in the Dong Nam Industrial Park, Vietnam.

[16] **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.

3.2.3 JA Solar Holding Co. Ltd. (PRC)
JingAo Solar Co. Ltd. (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, the production capacity was 2.8 GW for cells, 1.2 GW for modules, and 1 GW for wafers at the end of 2011. For 2012, an increase in module capacity to 2 GW is foreseen. For 2011, sales of 1,695 MW are reported.

3.2.4 Yingli Green Energy Holding Company Ltd. (PRC)
Yingli Green Energy (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 deals with the whole set, from solar wafers, cell manufacturing and module production. According to the company, production capacity reached 1.85 GW at the end of 2011. In August 2012, the company reached a total production capacity of 2.45 GW. The financial statement for 2011 reported shipments of 1.6GW.
In January 2009, Yingli acquired Cyber Power Group Limited, a development stage enterprise designed to produce polysilicon. Through its principle operating subsidiary, Fine Silicon, the company started trial production of solar-grade polysilicon in late 2009, and was still ramping up to full production capacity of 3,000 metric tons per year at the end of 2011. However, the financial results indicate that the company has written off its investment in Fine Silicon and according to other media reports the production is now closed down.
In January 2010, the Ministry of Science and Technology of China approved the 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.

3.2.5 Trina Solar Ltd, PRC (PRC)
Trina Solar (www.trinasolar.com) was founded in 1997 and went public in December 2006. The company has inte-

grated product lines, from ingots to wafers and modules. In December 2005, a 30 MW monocrystalline silicon wafer product line went into operation. According to the company, the production capacity was 1.2 GW for ingots and wafers and 1.9 GW for cells and modules at the end of 2011. For 2011, it is planned to expand the capacities to 2.4 GW for cells and modules. For 2011, shipments of 1.51 GW were reported.
In January 2010, the company was selected by the Chinese Ministry of Science and Technology to establish a State Key Laboratory to develop PV technologies within the Changzhou Trina PV Industrial Park. The laboratory is 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 to bring together technical capabilities from the company's strategic partners, including customers and key PV component suppliers, as well as universities and research institutions.

3.2.6 Motech Solar (Taiwan/PRC)
Motech Solar (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 2011 was given as 1.5 GW. For 2011, a combined production of 1.1 GW was reported.
In 2007, Motech Solar's Research and Development Department was upgraded to Research and Development Centre (R&D Centre), with the aim not only to improve the present production processes for wafer and cell production, but to develop next generation solar cell technologies. At the end of 2009, the company announced that it acquired the module manufacturing facilities of GE in Delaware, USA.

3.2.7 Canadian Solar Inc. (PRC)
Canadian Solar Inc. (CSI) (www.canadiansolar.com) was founded in Canada in 2001 and was 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, it had 228 MW of ingot and wafer capacity, 1.5 MW cell capacity and 2.1 GW module manufacturing capacity (1.9 GW in China, 218 MW in Ontario, Canada) in 2011. For 2011, the company reported sales of 1.32 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 at 1.05 GW [Pvn 2012].

3.2.8 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 inter-digitated 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 a 22% efficient solar cell, called Pegasus, that is designed for non-concentrating applications.
SunPower conducts its main R&D activity in Sunnyvale, California, and has its cell manufacturing plants in the Philippines and Malaysia. In 2011, the company had two cell manufacturing plants outside of Manila, but decided to close down Fab. No 1 early 2012. Fab. No 1 had a nameplate capacity of 125 MW and Fab. No 2 has another nameplate capacity of 575 MW. Fab. No. 3, a joint venture with AU Optronics Corporation (AUO), with a planned capacity of 1.4 GW, is currently in a ramp-up phase with a production capacity of 600 MW at the end of 2011. 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 2011 was reported at 922 MW.

3.2.9 Gintech Energy Corporation (Taiwan)
Gintech (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 260MW and increased to 1,170 MW at the end of 2011. The company plans to expand capacity to 1.5GW in 2012. In 2011, the company had a production of 882 MW [Pvn 2012].

3.2.10 Sharp Corporation (Japan/Italy)
Sharp (www.sharp-world.com) started to develop solar cells in 1959 and commercial production got under way in 1963. Since its products were mounted on “Ume”, Japan's first commercial-use artificial satellite, in 1974, Sharp has been the only Japanese maker to produce silicon solar cells for use in space. Another milestone was achieved in 1980, with the release of electronic calculators, equipped with single-crystal solar cells.
In 2011, Sharp had a production capacity of 1,070 MWp/year, and shipments of 857 MW (637 MW c-si and 220-tf) were reported [Pvn 2012]. Sharp has two solar cell factories

in Japan, Katsuragi, Nara Prefecture, (550 MW c-Si and 160 MW a-Si their triple-junction thin-film solar cell) and Osaka (200 MW c-Si and 160 MW a-Si), and one together with Enel Green Power and STMicroelectronics in Catania, Italy (initial capacity 160 MW at the end of 2011), six module factories and the Toyama factory to recycle and produce silicon. Three of the module factories are outside Japan, one in Memphis, Tennessee, USA, with 100 MW capacity, one in Wrexham, UK, with 500 MW capacity and one in Nakornpathom, Thailand.

3.2.11 Hareon Solar Technology Co., Ltd.
Haeron Solar (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 manufacture 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, the production capacity will be increased to over 2 GW for cells and 1 GW for modules in 2012. For 2011, a production of 855 MW is reported [Pvn 2012].

3.2.12 JinkoSolar Holding Co., Ltd.
Jinko Solar (www.jinkosolar.com) was founded by HK Paker Technology Ltd in 2006. Starting from up-stream 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 at the New York Stock Exchange. According to the company, it had manufacturing capacities of 1.2 GW each for wafers, solar cells and solar modules at the end of 2011. For 2011, the company reported sales of about 812.6 MW (760.8 modules and 51.8 cells).

3.2.13 Neo Solar Power Corporation (Taiwan)
Neo Solar Power (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 2011 was 1.3 GW. In 2011, the company had shipments of about 800 MW [Pvn 2012].

3.2.14 Q-Cells AG (Germany/Malaysia)
Q-Cells SE (www.qcells.de) was founded at the end of 1999 and is based in Thalheim, Sachsen-Anhalt, Germany. Solar cell production started in mid 2001, with a 12 MWp production line. The nominal capacity was 1.1 GW by the end of 2011, 500 MW in Germany and 600 MW in Malaysia. In the 2011 Annual Presentation, the company stated that production was 783 MW, including 66 MW of CIGS thin films from Solibro in 2011. Crystalline silicon solar cell production was 717 MW, 294 MW in Germany and 423 MW in Malaysia.
In the first half of the last decade, Q-Cells broadened and diversified its product portfolio by investing in various other companies, or forming joint ventures. Since the first half of 2009, Q-Cells has sold most of these holdings and now has one fully-owned solar cell manufacturing subsidiary, Solibro (CIGS).
In April 2012, the company filed for insolvency and was actively seeking a buyer of the operational business. On 29 August 2012, the creditors of Q-Cells approved the sale of the company to the South Korean conglomerate Hanwha.

3.2.15 Hanwha Solar One (PRC/South Korea)
Hanwha Solar One (www.hanwha-solarone.com) was established in 2004 as Solarfun Power Holdings, by the electricity meter manufacturer, Lingyang Electronics, the largest Chinese manufacturer of electric power meters.
In 2010, the Korean company, Hanwha Chemical, acquired 49.99% of the shares and a name change was performed in January 2011. The company 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.
As of 30 March 202, the company reported the following capacities: 1.5 GW PV module production capacity, 1.3 GW of cell production capacity, 800 MW of ingot and wafer production capacity.
The 2011 annual production was reported with 367 MW ingots, 383 MW wafers, 687 MW solar cells and 939 MW modules.

3.2.16 Kyocera Corporation (Japan)
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 mass production of multicrystalline silicon solar cells in 1982. In 1993, Kyocera started as 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, Mexico (since 2004) and in Kadan, Czech Republic (since 2005).

In 2011, Kyocera had a production of 660 MW, and 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. Kyocera is planning to increase its current capacity of 800 MW in 2011 to 1 GW in 2012.

3.2.17 Renewable Energy Corporation AS (Norway/Singapore)

REC's (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 located in Høvik, Norway, 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 closure announced in March 2012, was the wafer factory in Glomfljord with a 300 MW capacity for multicrystalline wafers, whereas the 650 MW wafer plant at at Herøya continues operation. In 2012, production of solar cells and modules will only be done at REC Solar Singapore, which operates an integrated site for wafers, solar cells and modules production, with a capacity of 750 MW. In 2011, production was reported with 1,072 MW wafers, 699 MW modules and approximately 640 MW of cells.

3.2.18 TIANWEI Group (PRC)

Tianwei Group (www.btw.cn/en) is an affiliate of China South Industries Group Corporation (CSGC) and has various businesses, e.g. electricity transmission equipment, wind and photovoltaics (thin films and crystalline silicon). New Energy Holdings Co., Ltd. (www.twnesolar.com) is an integrated silicon solar cell company and has six subsidiaries, including the US silicon manufacturer Hoku Corporation. In 2007, the company invested in two 3,000 t polysilicon projects, namely Sichuan Xinguang Silicon Industry and Leshan Electric Power. However, it is not clear if the 6,000t capacity was reached, as some reports claim a shutdown of the plants in 2012. According to the company, it planned to increase the capacity of wafer, cell and modules to 1 GW each, by 2011, and 1.5GW, by 2012. For 2011, a cell production of 569 MW is reported [Pvn 2012].
Baoding TianWei Solar Films Co., Ltd. (www.btw-solarfilms.com) was set up in 2008. Phase I of the production was set-up with a capacity of 50 MW and the start of commercial operation was in the second half of 2009. The company plans to reach a capacity of 500 MW in 2015. For 2011, a production of 65 MW is reported [Pvn 2021].

3.2.19 LDK Solar Co. Ltd. (PRC)

LDK (www.ldksolar.com) was set up by the Liouxin Group, and is mainly known as a producer of polysilicon material. LDK Solar manufactures polysilicon, mono and multicrystalline ingots, wafers, cells, modules, systems, power projects and solutions. In 2010, the company set up a production line for solar cells, with a capacity of 120 MW, increased it to 1.7 GW in 2011 and plans to further increase it to 2.2GW in 2012. At the end of 2011, production capacities were as follows: 4.3 GW wafers, 1.7 GW solar cells, 1.5 GW solar modules. For 2011, the company reported a production of 590 MW solar cells, 840 MW solar modules and 1.5 GW of wafers.

3.2.20 Changzhou EGing Photovoltaic Technology Co. Ltd.

EGING PV (www.egingpv.com) was founded in 2003 and works along the complete photovoltaic industry value chain, from the production of monocrystalline furnaces, quartz crucibles, 5-8 inch monocrystalline silicon ingots, supporting equipment of squaring and wire sawing, monocrystalline silicon wafers, solar cells, and solar modules. According to the company, it has a production capacity of 1 GW across the complete value chain of ingot, wafer, cell and modules at the end of 2011. For 2011, sales of 584 MW were reported.

3.3 Polysilicon supply

The rapid growth of the PV industry since 2000 led to the 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 around 500 $/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 2011 total production.
The massive production expansions, as well as the difficult economic situation, led to a price decrease throughout 2009, reaching about 50–55 $/kg at the end of 2009, with a slight upwards tendency, throughout 2010 and early 2011, before prices dropped significantly and in August 2012 were trading in the 30 $/kg (23 €/kg) range for con-

tracted silicon and 20 $/kg (15 %/kg) on the spot market. For 2011, about 288,000 metric tons of solar grade silicon production, or double the 2010 volume were reported, sufficient for around 41 GW, under the assumption of an average materials need of 7 g/Wp [Gtm 2012]. China produced about 80,000 metric tons (sufficient to supply about 60 to 65 % of the domestic demand), and imported about 64,600 metric tons in 2011 [Cri 2012]. In 2011, China increased its production capacity to about 120,000 metric tons, but over half of the Chinese polysilicon manufacturers are small enterprises, and the annual production capacity is generally 1,000 - 3,000 metric tons.

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 tons 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 metric tons 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 have closed down their production in the first half of 2012. This is also the reason why China already imported 48,000 metric tons of silicon during the first seven months of 2012, 35% more than during the same period last year [Etc 2012].

Projected silicon production capacities available for solar in 2012 vary between 328,000 metric tons [Ihs 2012] and 410,330 metric tons [Ikk 2012]. The possible solar cell production will, in addition, depend on the material used per Wp. The current world-wide average is about 6 g/Wp.

3.3.1 Silicon production processes

The high growth rates of the photovoltaic 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 work-horses of the polysilicon production industry for the near future.

Siemens process – In the late 1950s, the Siemens reactor was developed and has been the dominant production route ever since. About 80% of total polysilicon manufactured world-wide was made with a Siemens-type process in 2009. 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 – 1,175°C at which trichlorsilane, with the help of the hydrogen, decomposes to elemental silicon and deposits as a thin-layer film onto the filaments. Hydrogen Chloride (HCl) 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°C, that the filaments do not start to melt. Second, 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 to use 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 onto 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 are suspended by the upward flow of gases. At the operating temperatures of 750°C, the silane gas is reduced to elemental silicon and deposits on the surface of the silicon seeds. The growing seed crystals fall to the bottom of the reactor where they are 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 to produce 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 material for solar cells.

3.4 Polysilicon Manufacturers

World-wide more than 100 companies produce or started up polysilicon production. The following list gives a short description of the ten largest companies in terms of production in 2011. More information about additional polysilicon companies and details can be found in various market studies and the country chapters of this report.

3.4.1 OCI Company (South Korea)

OCI Company Ltd. (formerly DC Chemical) (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 metric ton P1 plant in December 2007. The 10,500 metric ton P2 expansion was completed in July 2009 and P3 with another 10,000 metric tons brought the total capacity to 27,000 metric tons at the end of 2010. The debottlenecking of P3, took place in 2011, and increased the capacity to 42,000 tons at the end of the year. Further capacity expansions P4 (20,000 tons) and P5 (24,000 tons) 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 metric tons by 2013.
For 2011, a production of 34,725 metric tons is reported [Gtm 2012].
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 has signed a PPA with CSP Energy, Texas, for a 400 MW solar farm in San Antonio, TX.

3.4.2 Wacker Polysilicon (Germany)

Wacker Polysilicon AG (www.wacker.com), is one of the world's leading manufacturers of hyper-pure polysilicon for the semiconductor and photovoltaic industry, chlorosilanes and fumed silica. In 2011, Wacker increased its capacity to over 40,000 metric tons and reported sales of 32,000 metric tons. The 15,000 metric tons factory in Nünchritz (Saxony), Germany, started production in 2011. In 2010, the company decided to build a polysilicon plant in Tennessee with 15,000 tons capacity. The groundbreaking of the new 18,000 metric ton factory was in April 2011, and the construction should be finished at the end of 2013. In addition, the company is expanding the Burghausen capacity by 5,000 metric tons in 2012 and together with a further expansion of the Nünchritz factory by 5,000 metric tons, the company plans to have 70,000 metric tons of production capacity in 2014. Total polysilicon production is reported with 33,885 metric tons in 2011 [Gtm 2012].

3.4.3 Hemlock Semiconductor Corporation (USA)

Hemlock Semiconductor Corporation (www.hscpoly.com) is based in Hemlock, Michigan. The corporation is a joint venture of 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 tons of polycrystalline silicon and production at the expanded Hemlock site (19,000 tons) started in June 2008. A further expansion at the Hemlock site, as well as a new factory in Clarksville, Tennessee, was started in 2009 and is still ongoing. Total production capacity was 46,000 metric tons in 2011 and the expansion to 56,000 metric tons should be finalised in 2012. For 2011 a production of 32,400 metric tons is reported [Gtm 2012].

3.4.4 GCL-Poly Energy Holdings Limited (PRC)

GCL-Poly (www.gcl-poly.com.hk) was founded in March 2006 and started the construction of their Xuzhou polysilicon plant (Jiangsu Zhongneng Polysilicon Technology Development Co. Ltd.) in July 2006. Phase I has a designated annual production capacity of 1,500 tons 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 metric tons and 8 GW of wafers. For 2011, the company reported a production of 29,414 metric tons of polysilicon with sales of 2,812 metric tons of polysilicon and 4.45 GW wafers.
In August 2008, a joint-venture, Taixing Zhongneng (Far East) Silicon Co. Ltd., started pilot production of trichlorsilane. Phase I will be 20,000 tons, with an expansion to 100,000 metric tons underway.
The company invested in the downstream business of solar. GCL Solar System Limited (SSL) is a wholly-owned subsidiary of GCL-Poly Energy Holdings Limited 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.

3.4 5 Renewable Energy Corporation AS (Norway)

REC's (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 located in Høvik, Norway has five business activities, ranging from

silicon feedstock to solar system installations.
In 2005, Renewable Energy Corporation AS (“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 Advanced Silicon Materials LLC (ASiMI) and REC Solar Grade Silicon LLC (SGS). Production capacity at the end of 2011 was around 20,000 metric tons and according to the company, 16,672 metric tons electronic grade silicon was produced in 2011.

3.4.6 MEMC Electronic Materials Inc. (USA/Italy)
MEMC Electronic Materials Inc. (www.memc.com) has its headquarters in St. Peters, Missouri. It started operations in 1959 and the company's products are semiconductor-grade wafers, granular polysilicon, ultra-high purity silane, trichlorosilane (TCS), silicon tetraflouride (SiF4), sodium aluminium tetraflouride (SAF). In February 2011, MEMC and Samsung announced a 50/50 joint venture to build a polysilicon plant in Korea with an initial capacity of 10,000 metric tons in 2013 [Mem 2011]. However, in December 2011 the company announced to idle its 6,000 metric ton Merano, Itlay factory in a major restructuring plan [Mem 2011b]. MEMC's production capacity at the end of 2011 was 15,000 metric tons [Sol 2012a]. Production was reported with 13,661 metric tons for 2011 [Gtm 2012].
MEMEC invested in the downstream business and acquired SunEdison, a developer of solar power projects and a solar energy provider, in 2009. During 2011 the company developed and acquired various projects. At the end of 2011, SunEdison had 255 MW under construction and 3 GW of projects in the pipeline.

3.4.7 LDK Solar Co. Ltd. (PRC)
LDK (www.ldksolar.com) was set up by the Liouxin Group, a company which manufactures personal protective equipment, power tools and elevators. With the formation of LDK Solar, the company is diversifying into solar energy products. LDK Solar went public in May 2007. In 2008, the company announced the completion of the construction and the start of polysilicon production in its 1,000 metric tons polysilicon plant. According to the company, the total capacity was 12,000 metric tons at the end of 2010, which will be increased to 25,000 tons in 2011. In 2011, polysilicon sales were reported at 10,455 metric tons.

3.4.8 Tokuyama Corporation (Japan)
Tokuyama (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 5,200 tons in 2008 and has expanded this to 9,200 tons in 2010. In February 2011, the company broke ground for a new 20,000 ton facility in Malaysia. The first phase with 6,200 metric tons should be finished in 2013 and the second phase with 13,800 metric tons in 2014. For 2011 a production of 8,800 tons is reported [Gtm 2012].
A verification plant for the vapour to liquid-deposition process (VLD method) of polycrystalline silicon for solar cells has been completed in December 2005. According to the company, steady progress has been made with the verification tests of this process, which allows a more effective manufacturing of polycrystalline silicon for solar cells.
Tokuyama has decided to form a joint venture with Mitsui Chemicals, a leading supplier of silane gas. The reason for this is the increased demand for silane gas, due to the rapid expansion of amorphous/microcrystalline thin-film solar cell manufacturing capacities.

3.4.9 Kumgang Korea Chemical Company (South Korea)
Kumgang Korea Chemical Company (KCC) (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 to manufacture 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 6,000 tons. For 2011 a production of 5,500 metric tons is reported [Gtm 2012].

3.4.10 Daqo New Energy Co., Ltd. (PRC)
Daqo New Energy (www.dqsolar.com) is a subsidiary company of the Daqo Group and was founded by Mega Stand International Limited in January 2008. The company started to build a high-purity polysilicon factory, with an annual output of 3,300 tons in the first phase in Wanzhou. The first polysilicon production line, with an annual output of 1,500 tons, started operation in July 2008. Production capacity in 2009 was 3,300 tons and reached more than 4,300 metric tons at the end of 2011. In the fourth quarter of 2012, expansion Phase 2 with 3,000 metric tons is scheduled to come on line and expansion Phase 3 with another 3,000 tons is scheduled for 2013. The company invested in the downstream business, ranging from 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 giving a capacity. The company reported a polysilicon production of 4,524 metric tons in 2011.

4. Outlook

In 2011, world-wide new investments into the renewable energy and energy efficiency sectors increased to a new record of $263 billion (€202 billion), including $25.8 billion (€19.8 billion) research and development spending [Pew 2012]. For the second year in a row, solar power attracted the largest amount of new investments into renewable energies and increased by 44% to $128 billion (€98.5 billion). Europe was still the leading region in terms of renewable energy investments, but renewable energy investments in the Asia/Oceania region again grew faster than in Europe, mainly through major investment increases in India, Japan and Indonesia.

With a growth of over 40%, the USA took the top rank with $48 billion (€36.9 billion), followed by China $45.5 billion (€35 billion), Germany $30.6 billion (€23.5 billion) and Italy $28 billion (€21.5 billion) [Pew 2012].

At the end of 2011, about 73% or $141.6 billion (€108.9 billion) of the $194.3 billion (€149.5 billion) global »green stimulus« money from governments, aimed to help relieve the effect of the recession, had reached the markets [Pew 2012]. For 2012 another $35 billion (€26.9 billion) are expected.

The Photovoltaic 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 photovoltaic manufacturers in 2011, only three had production facilities in Europe, namely First Solar (USA, Germany, Malaysia), Q-Cells (Germany and Malaysia) and REC (Norway and Singapore). However, REC closed down the production in Norway and First Solar has announced to close the factory in Germany by the end of the year. With the acquisition of Q-Cells by Hanwah Solar, it remains to be seen which production capacity will remain in Germany in the long run.

The focus of this report is on solar cells and modules, with some additional info about the polysilicon supply. Therefore, it is important to remember that the PV industry consists of more than that. and looking only at the cell production does not grasp 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), as well as the downstream industry (e.g. inverters, BOS components, system development, installations) has to be looked at as well.

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, were the beginning of an extraordinary PV market growth. Before the start of the Japanese market implementation programme in 1997, annual growth rates of the PV markets were in the range of 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 35 GW in 2011. This corresponds to a CAGR of a little more than 37% over the last twenty-one years. Statistically documented cumulative installations world-wide accounted for almost 70 GW in 2011. The interesting fact is, however, that cumulative production amounts to 90 GW over the same time period. Even if we do not account for the roughly 8 GW difference between the reported production and installations in 2011, there is a considerable 12 GW capacity of solar modules which are statistically unaccounted for. Parts of it might be in consumer applications, which do not contribute significantly to power generation, but the overwhelming part is probably used in stand-alone applications for communication purposes, cathodic protection, water pumping, street, traffic and garden lights, etc.

The temporary shortage in silicon feedstock, triggered by the high growth-rates of the photovoltaics industry over the last 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, like concentrator concepts, were introduced into the market much faster than expected a few years ago. However, the dramatic price decline for polysilicon and solar modules of more than 50% over the last two years, 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 that it is aiming for an industry consolidation with polysilicon companies, having at least a production capacity of 50,000 metric tons for polysilicon, and solar cell manufacturers, with at least 5 GW production capacity by 2015 [MII 2012].

Especially companies in their start-up and expansion phase, with limited financial resources and restricted access to capital, are struggling in the current market environment. This situation is believed will continue for at least the next few years and put further pressure on the reduction of the average selling prices (ASP), but the speed of price reductions will slow. The continuation of the financial crisis added pressure as it resulted in higher government bond yields, and ASPs have to decline even faster than previously expected to allow for a higher project internal rate of returns (IRRs). On the other hand, the rapidly declining module and system prices already opened up new markets, and this development will continue and offers the perspectives for further growth of the industry – at least for those companies with the capability to expand and reduce their costs at the same pace.

Even with the current economic difficulties, the number of market implementation programmes world-wide is still 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 systems high. In the long-term, growth rates for photovoltaics will continue to be high, even if economic frame conditions vary and can lead to a short-term slow-down.

This view is shared by an increasing number of financial institutions, which are turning towards 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 predicted that oil prices could well hit 100 $/bbl by the end of that year or early 2008 [IHT 2007]. After the spike of oil prices in July 2008, with close to 150$/bbl, prices have decreased due to the world-wide financial crisis and hit a low around 37$/bbl in December 2008. Since then, the oil price has rebounded and the IEA reported average prices for oil imports around 110 $/bbl since the second quarter of 2011, with a peak around 120 $/bbl in March and April 2012.

Oil demand has increased from about 84 million bbl/day in 1Q 2009, to around 90 million bbl/day in 2Q 2012, whereas the supply just increased from about 87 million bbl/day to 89 million bbl/day. For the rest of 2012 and 2013, modest demand growth of less than 1 million bbl/day is forecast, due to a combination of persistently high prices and a weak economic backdrop.

Even if no significant changes are forecasted by analysts at the moment for 2013, the fundamental trend, that increasing demand for oil will drive the oil price higher again, is still intact and will return as soon as the global economy recovers.

The Energy Watch Group estimated that world-wide spending on combustibles, fuels and electricity was between $5,500 billion (€4,231 billion) to 7,500 billion (€5,769 billion) in 2008 [Ewg 2010]. Between 2007 and 2010 about $1,840 billion (€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 World Bank [IEA

2011]. With 2007 to 2010 PV system prices, this subsidy would have been sufficient to install about 340 GW of PV systems world-wide. With the current system cost around 3 $/Wp (2.3 %/Wp), the amount would be sufficient to install 610 GW of photovoltaic electricity systems.

The FT 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 FT [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.*

The joint study estimates that energy consumption could be reduced by 25 EJ (600 Mtoe) – or the combined current consumption of Japan and Australia - if the subsidies are phased out between now and 2020. The consumption cut would save the equivalent of the current carbon dioxide emissions of Germany, France, Italy, and Spain.

Over the last 20 years, numerous studies about the potential growth of the photovoltaic industry and the implementation of photovoltaic electricity generation systems were produced. In 1996, the Directorate-General for Energy of the European Commission published a study »Photovoltaics in 2010« [EC 1996]. The medium scenario of this study was used to formulate the White Paper target of 1997, to have a cumulative installed capacity of 3 GW in the European Union by 2010 [EC 1997]. The most aggressive scenario in this report predicted a cumulative installed PV capacity of 27.3 GW world-wide and 8.7 GW in the European Union for 2010. This scenario was called »Extreme scenario« and it was assumed that in order to realise it a number of breakthroughs in technology and costs, as well as continuous market stimulation and elimination of market barriers, would be required to achieve it. The reality check reveals that even the most aggressive scenario is lower than what we expect from the current developments. At the end of 2010, PV systems with a cumulative capacity of over 39 GW world-wide and over 29 GW in Europe were generating electricity. The installations increased further to almost 70 GW world-wide and 52 GW in Europe at the end of 2011.

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 or financing costs. Despite the fact that PV system components are world-wide commodity products, the actual price for installed PV systems differs significantly. In the second quarter of 2012, the average system price for systems smaller 100 kWp was in the range of 1.78 €/Wp (2.3 $/Wp) in Germany, but between 6 and 6.5 $/Wp (4.6 – 5.0 €/Wp) in California and Japan [Blo 2012, Bsw 2012]. According to Bloomberg New Energy Finance (BNEF), one reason for the higher prices in California and Japan is the fact that installers are not passing on the full benefit of PV system price decline to their customers. BNEF expects a further price reduction there inline with the decrease of incentives. Engineering, Procurement and Construction (EPC) quotes for large systems are already much lower and turnkey system prices as low as 1 €/Wp (1.3 $/Wp) have been reported for projects to be finished in 2013 [Blo 2012].

In some countries, like Germany or Italy, the installed PV capacity will exceed 30% and 20% of the installed thermal power plant capacities respectively. Already on 25 May 2012, more than 22 GW of solar power were on the German grid, covering more than 30% of the total electricity demand at noon. Together with the respective wind capacities, wind and solar together will exceed 60% and 30% respectively. 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 of 500 to 600 $/kWh (385 – 460 €/kWh) storage capacity could fall to 200 $/kWh (155 €/kWh) storage capacity in 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 $/kWh (0.077 to 0.093 €/kWh) now, and should fall to 0.04 $/kWh (0.03 €/kWh) in 2020. With Levelised

Costs of Electricity (LCOE) from PV systems reaching 0.14 to 0.17 $/kWh (0.11 to 0.13 €/kWh) in the third quarter of 2012 [Blo 2012b], the additional storage cost already makes sense in markets with high peak costs in the evening, where only a shift of a few hours is required. Already in February 2012, BYD (Build your Dreams) and the State Grid Corporation of China (SGCC) have 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 Li-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 Photovoltaic 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. Table 1 shows the different scenarios of the Greenpeace/EREC study, as well as the different 2011 IEA *World Energy Outlook scenarios* and the IEA PV Technology Roadmap. It is interesting to note that the 2015 capacity values of the IEA Current Policy and 450ppm Scenarios (in red) are already reached or exceeded in 2011. With forecasted new installation of between 84 to 118 GW in 2012, 2013 and 2014 even the Greenpeace revolution scenario is no longer fictional thinking [Blo 2012].

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 constant 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 International Energy Agency's Energy Technology Perspectives 2010 stated that for their current Baseline Scenario, the overall investments in energy supply and use, for the period between 2010 and 2050, totals $270 trillion[17] (€ 208 trillion) [IEA 2010]. The BLUE-Map scenario, which would limit the concentration of Greenhouse Gases at 450 ppm, has an additional financing need of $46 trillion (€35.4 trillion), but at the same time the cumulative fuel savings of this scenario compared to the Baseline would be $112 trillion (€86.2 trillion), or more than twice the investment cost. This clearly indicates the huge societal benefit of a more aggressive climate change approach.

In the electricity sector, the investments for the baseline scenario over the next 40 years would amount to $23.5 trillion (€18.1 trillion) and about $15 trillion (€11.5 trillion) would be needed for new power-generation plants. The average BLUE-Map scenario has an additional financing need of $9.3 trillion (€7.2 trillion), mostly in power generation capacity.

It is worthwhile to mention that the high renewable BLUE Map scenario, with 75% electricity from renewable, has the highest additional investment cost of $12.9 trillion (€10 trillion), but this is less than 30 years of the average annual subsidies paid to fossil energy between 2007 and 2010.

Table 1: Evolution of the cumulative solar electrical capacities until 2050 [Gre 2012, IEA 2010a, IEA 2011a]

Year	**2010** [GW]	**2015** [GW]	**2020** [GW]	**2030** [GW]	**2035** [GW]
ACTUAL INSTALLATIONS	**70**				
Greenpeace* (reference scenario)		88	124	234	290
Greenpeace* ([r]evolution scenario)		234	674	1,764	2,420
IEA Current Policy Scenario**		60	161	268	314
IEA New Policy Scenario		112	184	385	499
IEA 450ppm Scenario**		70	220	625	901
IEA PV Technology Roadmap***		76	210	872	1,330

* 2035 values are extrapolated, as only 2030 and 2040 values are given
** 2015 values are extrapolated, as only 2009 and 2020 values are given
*** 2015 and 2035 values are extrapolated, as only 2010, 2020, 2030 and 2040 values are given

[17] In 2010 U.S.$

Due to the long life-time of power plants (30 to 50 years), the decisions taken now will influence the socio-economic and ecological key factors of our energy system in 2020 and beyond. In addition, a 2003 IEA study pointed out that fuel costs will be in the same order of magnitude as investment in infrastructure. The price development over the last eight years has exacerbated this trend and increased the scale of the challenge, especially for developing countries.

The above-mentioned solar photovoltaic scenarios will only be possible if solar cell and module manufacturing are continuously improved, and novel design concepts can be realised, as with current technology the demand for some materials, like silver, would dramatically increase the economic costs for this resources within the next 30 years. Research to avoid such kinds of problems is underway and it can be expected that such bottle-necks will be avoided.

The photovoltaic industry is still changing from a MW size industry into a mass-producing industry aiming for multi GW production. This development is connected to an 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 lower-priced products, customers will buy more solar systems and it is expected that the PV market will show an accelerated growth rate. 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 the advantage of the big companies made possible by economies of scale that come with large production volumes, they have to specialise in niche markets with high value added in their products. The other possibility is to offer technologically more advanced and cheaper solar cell concepts.

Despite the fact that Europe – especially Germany – is still the biggest world market, the overall world market is gradually changing into a more balanced one. 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. Should the current trend in the field of world-wide production capacity increase continue, the European share will decrease further. At the moment, it is hard to predict how the market entrance of the new players all over the world will influence future developments of the markets.

A lot of the future market developments, as well as production increases, will depend on the realisation of the currently announced and ongoing world-wide PV programmes and production capacity increases. During 2011 and the first half of 2012, the announcements from new companies wanting to start a PV production, as well as established companies to increase their production capacities, continued to increase the expected overall production capacity.

Already for a few years, we have now observed a continuous rise of oil and energy prices, which highlights the vulnerability of 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, as a result of steep learning curves. Due to the fact that external energy costs, subsidies in conventional energies and price volatility risks are generally not yet taken into consideration, renewable energies and photovoltaics are still perceived as being more expensive in the market than conventional energy sources. Nevertheless, electricity production from photovoltaic solar systems has already proved now that it can be cheaper than residential consumer prices in a wide range of countries. In addition, renewable energies are, contrary to conventional energy sources, the only ones to offer a reduction of prices rather than an increase in the future.

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6. References

[ADB 2011] Asian Development Bank, *Asia Solar Energy Initiative: A Primer,* ISBN 978-92-9092-314-5, April 2011

[Blo 2012] Bloomberg new Energy Finance, PV Market Outlook Q3 2012, 7 August 2012

[Blo 2012a] Bloomberg new Energy Finance, Analyst Reaction - Solar, 17 August 2012

[Blo 2012b] Bloomberg new Energy Finance, Energy Research Note – Levelised Cost of Electricity Q3 2012, 18 July 2012

[Bsw 2012] Bundesverband Solarwirtschaft, Statuspapier Photovoltaik, June 2012

[Bun 2012] German Federal Network Agency (Bundesnetzagentur), Datenmeldungen für 2011

[Cri 2012] China Research and Intelligence Co., Ltd. (CRI), Research Report on China's Polysilicon Industry, 2012, May 2012

[Dai 2011] The Daily Star, Target 500 MW solar project, 15 May 2011, http://www.thedailystar.net/newDesign/news-details.php?nid=185717

[DEC 2011] Department of Energy & Climate Change, Press Release, 7 February 2011

[EC 1996] European Commission, Directorate-General for Energy, Photovoltaics in 2010, Office for Official Publications of the European Communities, 1996, ISBN 92-827-5347-6

[EC 1997] Energy for the Future: Renewable sources of energy; White Paper for a Community Strategy and Action Plan, COM(1997)599 final (26/11/97)

[EC 2007] C 3/2007 - Tarifs réglementés de l'électricité en Espagne Official Journal of the European Communities, C 43/50 (27 February 2007)

[EEG 2000] Gesetz über den Vorrang Erneuerbaren Energien (Erneuerbare-Energien-Gesetz – EEG), Bundesgestzblatt Jahrgang 2000 Teil I, Nr. 13, p.305 (29.03.2000)

[Epi 2012] European Photovoltaic Industry Association, 2012, *Global Market Outlook for Photovoltaics until 2016*

[Ern 2011] Ernest & Young, Renewable energy country attractiveness indicator, November 2011, Issue 31

[Etc 2012] Facilitate Smooth Import to China, E-to-China.com, Press Release 4 September 2012

[Ewg 2010] Energy Watch Group, March 2010, Abschätzung der jährlichen weltweiten Ausgaben für Energieversorgung http://www.energywatchgroup.org

[FiT 2010] Financial Times, 6 June 2010, IEA counts $550 billion energy support bill

[Fir 2012] First Solar, Press Release, 17 April 2012

[Gaz 2012] Supplemento n. 143 alla Gazzetta n. 159 del 10/07/2012, Ministero dello Sviluppo Economico, decreto ministeriale 5 luglio 2012; Attuazione dell'articolo 25 del decreto legislativo 3 marzo 2011, n. 28, recante incentivazione della produzione di energia elettrica da impianti solari fotovoltaici (cd. Quinto Conto Energia)

[GoA 2006] Ley 26.190 - Ley de Energía Eléctrica (2006), Boletín Oficial de la República de Argentina, Número 31.064 http://www.diputados-catamarca.gov.ar/ley/B0020107.PDF

[GoB 2012] Bulgarian State Gazette, 10 April 2012, Decree 147/2012 from 28 March 2012, http://dv.parliament.bg/DVWeb/showMaterialDV.jsp?idMat=63208

[GoC 2012] Strategic Energy Plan, 28 February 2012 http://www.gob.cl/especiales/estrategia-nacional-de-energia/

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

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

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

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

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

[GoS 2012] Slovakian Ordinance No. 225/2011, 11 July 2011 http://www.urso.gov.sk/doc/legislativa/vyhl_225-2011.pdf

[GoS 2012a] Spanish Royal Decree 1/12, published on 28 January 2012 http://www.boe.es/boe/dias/2012/01/28/pdfs/BOE-A-2012-1310.pdf

[GSE 2012] Gestore Servizi Energetici, Rapporto Statistico 2011 – Solare Fotovoltaico, 14 May 2012

[GSE 2012a] Gestore Servizi Energetici, conto energia – contatore fotovoltaico, 31 August 2012

[Gtm 2012] Greeentech Media Research, Polysilicon 2012 – 2016: Supply, Demand & Implications for the Global PV Industry, 18 January 2012

[Hen 2012] R. Hensley, J. Newman and M. Rogers, Battery technology charges ahead, McKinsey Quarterly, July 2012

[IEA 2010] International Energy Agency, 2010, Energy Technology Perspectives – Scenarios & Strategies to 2050, ISBN 978-92-64-08597-8

[IEA 2010a] International Energy Agency, 2010, PV Technology Roadmap

[IEA 2011] Joint report by IEA, OPEC, OECD and World Bank on fossil-fuel and other energy subsidies: An update of the G20 Pittsburgh and Toronto Commitments http://www.oecd.org/env/49090716.pdf

[IEA 2011a] International Energy Agency, 2011, World Energy Outlook, ISBN 978-92-64-12413-4

[IEA 2012] International Energy Agency, Medium-Term Renewable Energy Market Report 2012 - Market Trends and Projections to 2017, 182 pages, ISBN 978-92-64-17799-4 (2012)

[IEA 2012a] International Energy Agency, Co-operative Programme on Photovoltaic Power Systems, National Survey Report of PV Power Applications in China 2011, 15 August 2012

[IEA 2012b] International Energy Agency, Co-operative Programme on Photovoltaic Power Systems, National Survey Report of PV Power Applications in Korea 2011, 20 June 2012

[IEA 2012c] International Energy Agency, Co-operative Programme on Photovoltaic Power Systems, Trend Preview, 17 August 2012

[Ihs 2012] iSupply, Surplus Supply of Polysilicon Pressures Pricing—but not all Polysilicon Prices are Equal, Press Release 18 April 2012

[Ikk 2012] Osamu Ikki, PV Activities in Japan, Volume 18, No 7, July 2012

[Ims 2012] IMS research, Press Release 22 August 2012

[MEI 2011] Ministère de l`Économie, de l'industrie et de l'emploi, Press Release, 24 February 2011

[MII 2012] Ministry of Industry and Information Technology, 太阳能光伏产业"十二五"发展规划 (issuance of the solar photovoltaic industry, "second five" development plan"), 24 February 2012 http://www.miit.gov.cn/n11293472/n11293832/n12771663/14473764.html

[Min 2012] Paula Mints, CPV – To Infinity and Beyond!, Navigant Consulting Webinar, 18 July 2012

[NEA 2012] National Energy Administration, 可再生能源发展"十二五"规划发布 Press Release, 8 August 2012 http://www.nea.gov.cn/2012-08/08/c_131767651.htm

[Ont 2012] Ontario Power Authority, 10August 2012: Final FIT 2.0 http://fit.powerauthority.on.ca/august-10-2012-final-fit-20-program-documents-posted

[Pvm 2012] PV magazine, 30 July 2012, http://www.pv-magazine.com/news/details/beitrag/india--1-gw-milestone-crossed_100007931/

[Pvn 2012] PV News, May 2013, published by Greentech Media, ISSN 0739-4829

[Pho 2011] Photon International, March 2012

[Reu 2012] Reuters, 8 August 2012, China hikes 2015 solar power target by 40%

[RoI 2006] Presidential Regulation 5/2006, *National Energy Policy*, published 25 January 2006

[RoP 2008] Republic of the Philippines, Congress of the Philippines, Republic Act No. 9513 16 December, 2008, *AN ACT PROMOTING THE DEVELOPMENT, UTILIZATION AND COMMERCIALIZATION OF RENEWABLE ENERGY RESOURCES AND FOR OTHER PURPOSES*

[Sei 2012] Solar Energy Industry Association (SEIA), US Solar Market Insight, US Solar Industry Year in Review 2011

[Sol 2012] Solarbuzz, *Supply/Demand Balance Restored to PV Industry in Second Half of 2012*, 25 June 2012 (http://www.solarbuzz.com)

[Sol 2012a] Solar PV Investor, Polysilicon Capacity 2010 – 2013

[Sys 2012] Systèmes Solaires, le journal du photovoltaique n° 7 – 2012, Photovoltaic Energy Barometer, April 2012, ISSN 0295-5873

[Unb 2011] UNB connect, ADB assures fund for 500 MW solar system, 4 June 2011, http://www.unbconnect.com/component/news/task-show/id-49440

[Unb 2012] UNB connect, 50,000 new rural homes getting solar electricity every month , 26 June 2012, http://unbconnect.com/component/news/task-show/id-80519

[UNEP 2008] Reforming Energy Subsidies – Opportunities to Contribute to the Climate Change Agenda United Nations, United Nations Environment Programme, 2008, http://www.unep.org/pdf/pressreleases/reforming_energy_subsidies.pdf

[WoB 2010] The World Bank, May 2010, Winds of Change – East Asia's Sustainable Energy Future

[WoB 2012] The World Bank, 13 June 2012, Electricity from Solar Panels Transforms Lives in Rural Bangladesh

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Abstract

Photovoltaics is a solar power technology to generate Electricity using semiconductor devices, known as solar cells. A number of solar cells form a solar "Module" or "Panel", which can then be combined to solar systems, ranging from a few Watts of electricity output to multi Megawatt power stations.
The unique format of the Photovoltaic Status Report combines international up-to-date information about Research Activities with Manufacturing and Market Implementation Data of Photovoltaics. These data are collected on a regular basis from public and commercial studies and cross-checked 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. Yearly growth rates over the last decade were on average more than 40%, thus making photovoltaics one of the fastest growing industries at present. The PV Status Report provides comprehensive and relevant information on this dynamic sector for the public interested, as well as decision- makers in policy and industry.

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