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# The European Solar Power Sector Analysis:
## Vertical Integration and Progress towards Grid Parity

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# List of Abbreviations

| | |
|---|---|
| BIPV | Building-integrated photovoltaic |
| BOS | Balance of system |
| CSP | Concentrated solar-thermal power |
| DSO | Distribution system operator |
| EU | European Union |
| EU-25 | The EU member states since 2004: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, Netherlands, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom. |
| EU-27 | The EU member states since 2007: same as EU-25 plus Bulgaria and Romania. |
| FIT | Feed-in tariff |
| GHG | Greenhouse gases |
| GW | Gigawatt |
| GWh | Gigawatt hour |
| IEA | International Energy Agency |
| kW | Kilowatt |
| kWh | Kilowatt hour |
| M&A | Mergers and acquisitions |
| MW | Megawatt |
| MWh | Megawatt hour |
| NEA | Nuclear Energy Agency |
| OECD | Organisation for Economic Cooperation and Development |
| PE | Private equity |
| PV | Photovoltaic |
| R&D | Research and development |
| RE | Renewable energy |
| TGC | Tradable green certificates |
| TSO | Transmission system operator |
| UNEP | United Nations Environment Programme |
| VC | Venture capital |
| W | Watt |
| Wh | Watt hour |

# Chapter 1: Introduction

Since 2007, new solar photovoltaic (PV) capacity has come on-stream at a faster percentage rate than any other power source.[1] This is due largely to governments offering both supportive renewable energy policy environments and generous subsidies to solar power developments. From 2007 to early 2008, demand for solar PV systems was so high that solar cell manufacturers struggled to increase manufacturing capacity at a fast enough rate to meet demand. Total global installed solar PV capacity grew by 25 per cent during 2008 to 11,500 MW, from 9,200 MW at the end of 2007, which was in turn a 50 per cent increase from 2006 levels. This growth was made possible by a flood of new capital into the sector.

Among renewable power technologies, solar PV in particular has experienced an extraordinary acceleration of investment with approximately USD 31 billion invested in 2008 and a higher annual percentage rate of increase than hydro, wind, biomass and biofuels combined. Europe leads the world in the development of solar power, accounting for over 80 per cent of the world's solar PV market. Of the new solar PV capacity installed worldwide in 2007, 48 per cent was in Germany and 18 per cent in Spain. In 2008, 27 per cent of global new installed solar PV capacity was added in Germany and 45 per cent in Spain.[2]

More recently, the European solar PV sector has been badly affected by the global financial crisis and recession. Demand for solar PV systems fell dramatically from mid-2008, and as a result, it is anticipated that the price of silicon and solar modules will fall between 30 per cent and 40 per cent[3] in 2009.[4] The drop-off in demand for solar PV systems and shortage of available finance has also lead to a 44 per cent fall in investment in the clean energy sector in the first quarter of 2009 from the fourth quarter of 2008.[5]

As the European solar PV sector matures through a period of rapid growth and fierce competition, firms are striving to lower generation costs and to make solar PV power more competitive to the European consumer and wholesale markets, and as a consequence, solar PV has become less reliant on government incentives. The principle goals of firms in the solar PV sector are now to reach a point of ***consumer grid parity*** and to ***increase the price competitiveness of electricity generated by commercial solar power plants*** and transmitted and distributed through the grid to a level comparable to traditionally produced electricity. It is anticipated that should either of these goals be reached, the solar PV market would grow signficantly as consumers would be offered a renewable, clean and price-competitive substitute to all or part of their fossil-fuel generated electricity needs.

While many internal and external factors contribute to the competitiveness of solar power relative to fossil fuel power, this report aims to clarify how firms in the solar PV industry are moving towards these two goals through:

- the improvement of solar PV systems to convert sunlight into electricity, or simply the ***power conversion factor***; and
- the ***reduction in the total cost of ownership***, including acquiring, installing and operating solar PV power systems.

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1 REN21, "Renewables 2007 Global Status Report", March 2008. Available at <ren21.net/pdf/RE2007_Global_Status_Report.pdf>.
2 European Photovoltaic Industry Association, Global Market Outlook for Photovoltaics until 2013, April 2009. Available at <epia.org/fileadmin/EPIA_docs/publications/epia/Global_Market_Outlook_Until_2013.pdf>
3 New Energy Finance, 'PV Costs to Plummet in 2009 – Driven by Silicon Costs, Oversupply and Growth of Thin Film', 11 December 2009. Available at <www.newenergymatters.com/?p=about&n=13>.
4 Greg Boutin, Roadmap for a Changed Landscape, Renewable Energy World, 18 December 2008. Available at <www.renewableenergyworld.com/rea/news/story?id=54348>.
5 New Energy Finance, '44% Plunge in Investment as Crisis Catches up with Clean Energy', 2 April 2009. Available at <www.newenergymatters.com/?p=about&n=13>.

**Methodology**

This report will begin by providing a structural overview of the European solar PV sector illustrating the interrelation of the key technological and commercial drivers of the sector. It will then provide a detailed analysis of each driver, describing the different technologies used in solar power generation, the market for solar power in Europe, the investment that has underpinned the sector's impressive growth and the incentive schemes offered by European governments. The analysis of government incentives in different European countries' solar PV markets will demonstrate how growth in the solar PV sector is contingent on attractive incentives.

The report will then examine the solar PV industry's value chain, focussing on the two most important commercial drivers of the solar PV sector, namely, the improvement of solar systems' power conversion efficiency and the reduction of total cost of ownership for solar PV systems.

**Improvement in the conversion efficiency of solar PV systems** relies heavily on the technological improvement of solar cells and modules, as well as the efficiency of other electrical components, which together contribute a comparatively small amount to total system loss. Different materials offer varying power conversion efficiency rates and cost benefits. Solar PV modules continue to deliver greater conversion efficiency than thin-film modules, however thin-film modules are traditionally cheaper to produce because of high silicon prices for solar PV modules. This report will discuss the different solar PV technologies and their performance properties, and track the technology improvements achieved by leading European solar cell and module manufacturers.

**Cost reductions** in the solar PV sector have been achieved largely through firms establishing production economies of scale and through vertical integration into multiple stages of the industry value chain. This report offers a detailed analysis of the European solar PV value chain including the relative value-added production costs at each stage. Using an indicative sample of 108 companies active in the sector, it illustrates how high demand in the sector led to multiple new entrants and industry fragmentation, and how different strategic integration models are employed to save costs and improve profitability by firms operating both upstream and downstream in the value chain.

# Chapter 2: The Solar PV Sector Overview

The amount of energy the sun transfers to earth is enormous. It is estimated that the energy from one hour of sunlight striking the earth's surface is greater than the entire energy demand for the whole planet for one year.[6] In the context of a growing demand in the global energy market and the increasingly noticeable effects of climate change, the need to utilise this clean energy source is widely accepted.

The European solar PV sector, as the global leader in solar PV development, has matured to a point where solar PV firms are now aiming to develop solar power systems that can operate profitably as competitors to fossil-fuel powered generators. On the consumer side this goal is termed "grid parity", referring to a situation where the levelised ownership cost of generating electricity using a solar PV system is equal to or less than the retail electricity price paid by consumers.[7] According to many analysts, including Q-Cells, the largest manufacturer of solar PV cells, the current target date for attaining consumer grid parity in parts of Europe is 2012.[8] On the large utility-scale commercial generation side, the industry goal is to generate solar power for transmission and distribution through the grid at a low enough cost for the generator to compete with fossil-fuel powered generators. Investment in large-scale commercial solar power generation continues to gather pace. However, at present the generation cost of fossil fuel based electricity is considerably lower and will remain so for the foreseeable future.

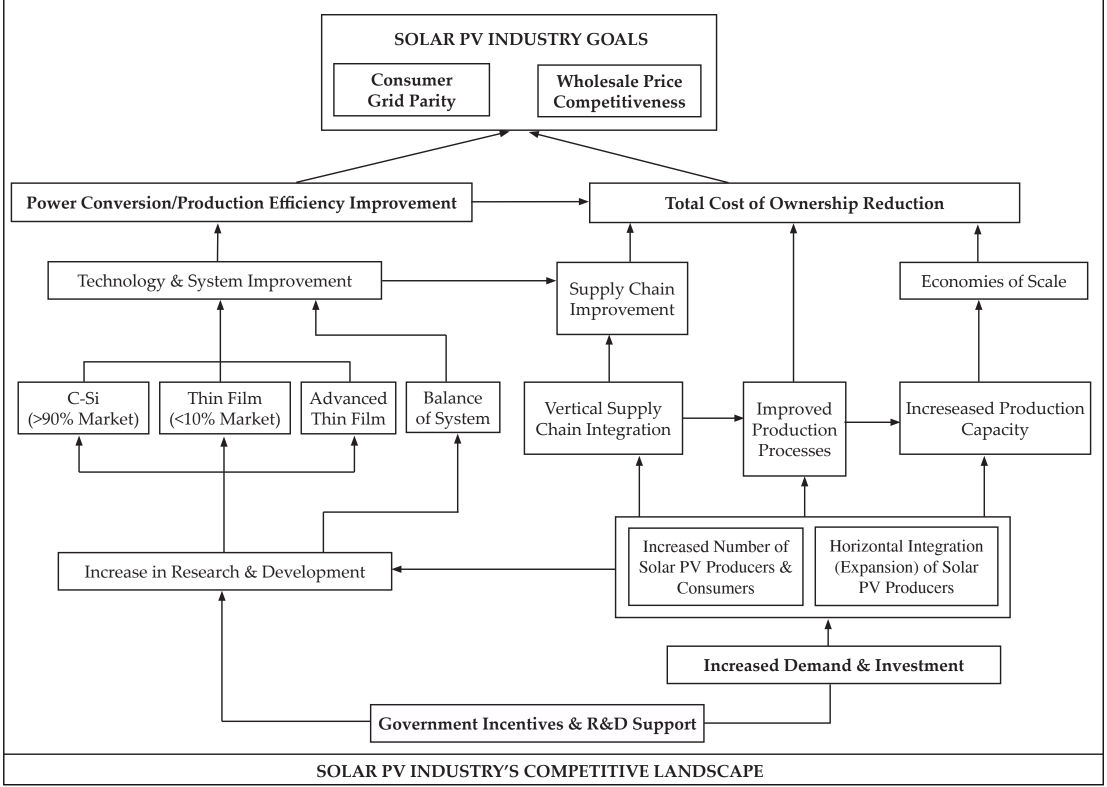
Until these goals are reached, development of the solar PV sector remains reliant on government incentives. The demand created by government incentives for solar power has prompted existing and new entrant solar PV firms to invest heavily in research and development (R&D) to improve the technology underpinning their solar cells, modules and systems. The increase in R&D investment has not only brought about considerable improvements in the power generation efficiency of traditional crystalline silicon-based solar cells, but has also spurred the development of alternative technologies such as thin film and advanced thin film.

Government-supported demand for solar PV has also driven an increase in investment. This has led to a greater number of firms in the sector, an improvement in production and manufacturing processes, the horizontal integration of firms through mergers and acquisitions, and vertical integration along the industry's value chain. The emergence of internal and external economies of scale, improved manufacturing processes and synergies offered by value chain integration have combined to reduce the total cost of solar systems whilst improving their reliability. Together, these factors are the key requirements in reducing the total cost of ownership of solar PV installations.[9]

The relationship between government incentive-driven demand, the key growth drivers in the industry, and the ultimate solar PV sector goals is illustrated in Figure 2.1.

6 Ken Zweibel et al, 'A Grand Solar Plan,' Scientific America, January 2008. Available at <www.scientificamerican.com/article.cfm?id=a-solar-grand-plan>.
7 IEA PVPS, Trends in Photovoltaic Applications, 2008. Available at <www.iea-pvps.org/products/download/rep1_17.pdf>.
8 Q Cells, Financial Year 2008. Available at <www.q-cells.com/medien/ir/praesentationen/2009/financial_year_2008.pdf>.
9 E. Ryabova, A Review of Solar Wafer Cleaning and Texturing Methods, 30 April 2009. Available at <www.renewableenergyworld.com/rea/news/article/2009/04/a-review-of-solar-wafer-cleaning-and-texturing-methods>.

**Figure 2.1 Diagrammatic representation of the solar PV industry**




## 2.1. Solar Power Technologies

Solar power generation utilises two distinct types of technology: solar PV which employs semi-conductive materials, such as silicon or cadmium telluride, to convert sunlight directly into electricity; and concentrated solar-thermal power (CSP) which uses large reflective surfaces to concentrate the sun's light to create heat which usually drives steam-powered electricity-generating turbines.

Because of the capital intensive nature of CSP installations, the CSP sector is dominated by large energy utilities and construction companies. Solar PV systems, by contrast, generally use prefabricated solar PV modules which are considerably cheaper, smaller and more versatile than CSP systems. Solar PV systems therefore serve the entire demand spectrum for solar power from individual residential users to large utility-scale commercial power generators.

### 2.1.1. Solar PV Power

Solar PV cells produce electricity through the interaction of light photons with electrons in a semiconductive material such as silicon.[10] There are two primary materials used in the manufacture of solar PV systems: crystalline silicon, which is employed in approximately

10 APS Project Sol. Available at <projectsol.aps.com/inside/inside_pv.asp>.

90 per cent of solar PV systems,[11] and thin-film materials which are collectively used in the remaining 10 per cent.[12]

### 2.1.1.1. *Solar PV Market*

Solar PV is one of the most rapidly expanding generating technologies in year-on-year percentage growth terms. The total installed capacity of solar PV in the EU-27 was approximately 4.9 GW in 2007, which was less than a tenth of that of wind power. This, however, represented an increase of over 40 per cent from 3.2 GW in 2006. The estimated figure for 2008 is approximately 9.5 GW, an increase of almost 94 per cent from 2007.

Germany is the world leader in terms of total installed capacity, while Spain is rapidly increasing its capacity (see Table 2.1). The European Photovoltaic Industry Association forecasts that the EU could have a total installed capacity of solar PV of 13.5 GW by 2010, and 100 GW in 2020.[13] These figures represent an increase of 42 per cent between 2008 and 2010, and a further 640 per cent increase between 2010 and 2020.

**Table 2.1: Total installed generating capacity of solar PV in selected countries of the EU in 2006 - 2008 (MW)**

| Country | 2006 | Change from 2006 to 2007 | 2007 | Change from 2007 to 2008 | 2008 (Estimate) |
|---|---|---|---|---|---|
| Germany | 2,743.0 | 40.2% | 3,846.0 | 39.1% | 5,351.0 |
| Spain | 175.0 | 319.3% | 733.8 | 364.0% | 3,404.8 |
| Italy | 50.0 | 140.4% | 120.2 | 164.1% | 317.5 |
| France | 33.9 | 37.6% | 46.7 | 95.4% | 91.2 |
| Belgium | 4.2 | 417.3% | 21.5 | 230.8% | 71.2 |
| Portugal | 3.4 | 425.6% | 17.9 | 280.3% | 68.0 |
| The Netherlands | 52.7 | 1.1% | 53.3 | 3.0% | 54.9 |
| Czech Republic | 0.8 | 369.9% | 4.0 | 1270.6% | 54.3 |
| Austria | 25.6 | 8.2% | 27.7 | 9.0% | 30.2 |
| Luxembourg | 23.7 | 1.0% | 23.9 | 2.0% | 24.4 |
| UK | 14.3 | 26.5% | 18.1 | 19.3% | 21.6 |
| Greece | 6.7 | 36.9% | 9.2 | 101.7% | 18.5 |
| Rest of EU | 15.1 | 10.7% | 16.7 | 44.2% | 24.1 |
| **TOTAL** | **3,148.4** | **56.9%** | **4,939.0** | **93.0%** | **9,531.6** |

Source: EurObserv'ER, Photovoltaic Barometer, No. 184, April 2008. Available at <www.energies-renouvelables.org/observ-er/stat_baro/observ/baro184.pdf>; and EurObserv'ER, Photovoltaic Barometer, No. 190 March 2009. Available at <eurobserv-er.org/pdf/baro190.pdf>

### 2.1.1.2. *Solar PV Investment*

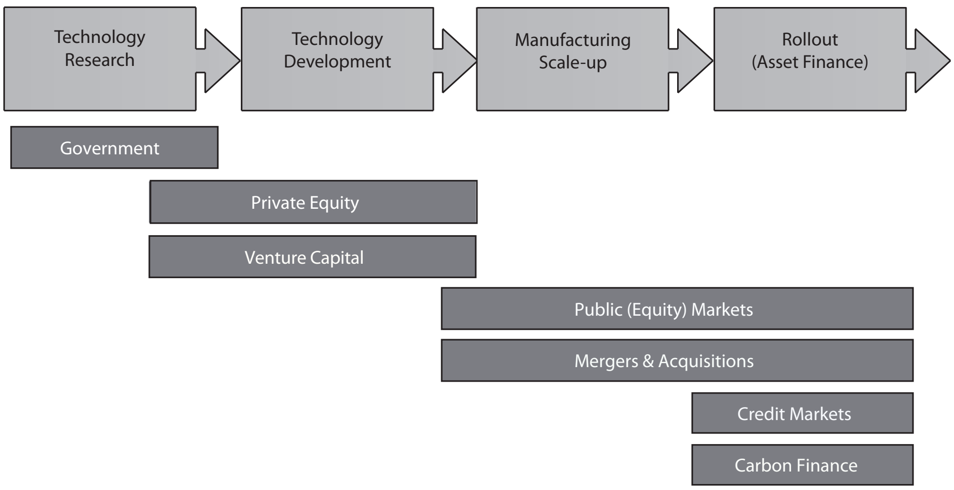
Investment in renewable energy has increased considerably in the past decade. The perceived investment risk in the sector has fallen, due in large part to the introduction of new government incentives such as feed-in tariffs (FITs) that offer developers a guaranteed price for all the renewable power they generate. As the perceived risks associated with renewable electricity

11 Solar Buzz, Solar Cell Technologies, April 2009. Available at < solarbuzz.com/Technologies.htm>.
12 E. Ryabova, 'A Review of Solar Wafer Cleaning and Texturing Methods,' Renewable Energy World, 30 April 2009. Available at <www.renewableenergyworld.com/rea/news/article/2009/04/a-review-of-solar-wafer-cleaning-and-texturing-methods>.
13 European Photovoltaic Industry Association and Greenpeace, Solar Generation V, September 2008. Available at <www.epia.org/fileadmin/EPIA_docs/documents/EPIA_SG_V_ENGLISH_FULL_Sept2008.pdf>.

development have fallen, a broader range of investors, with a wider array of financial instruments, have invested in the sector.

Different sources of finance are better suited to different stages in the life-cycle of a renewable energy technology. Figure 2.2 illustrates how research into new and innovative renewable energy (RE) technologies requires considerable support from the government, as well as private equity (PE) and venture capital (VC) investors, which are able to carry promising new technologies forward for mass commercialisation. Once a technology has been developed to the point where it is ready for scaling-up and widespread commercial application, public equity markets become the preferred source of finance, and merger and acquisition activity increases. Asset finance from the credit and carbon markets is also common at the later stages of a technology's life-cycle.

**Figure 2.2: Financing continuum for a typical renewable energy technology**




Source: Derived from New Energy Finance and the United Nations Environment Programme (UNEP), Global Trends in Sustainable Energy Investment 2008 – Dataset, July 2008. Available at <sefi.unep.org/fileadmin/media/sefi/docs/publications/data_2008.pdf>.

While new investment is spread across all RE technologies, three technologies, namely wind, solar and biofuels, attract the most investment (see Figure 2.3). In 2008, total new investment[14] in wind projects was USD 52 billion, slightly down from USD 53.7 billion in 2007, while investments in solar power projects rose to USD 34 billion in 2008 from USD 23.5 billion in 2007. Biomass saw a significant drop to USD 8 billion from USD 10.5 billion over the same 2007 to 2008 period, but it still remains a major technology in terms of levels of investment.[15]

The WilderHill New Energy Global Innovation Index (NEX), an index measuring the share price performance of 88 clean energy companies around the world, rose 48 per cent in 2007 to 455 points by January 2008, but fell to around 29 per cent to 133 points in the fourth quarter of 2008.[16] Solar share prices were particularly badly affected, falling 75 per cent on average between 2007 and 2008. Biomass and biofuel shares fell by 68 per cent as concerns were raised

14 New investment refers to third party investment of capital from outside of the renewable electricity sector. Merger and acquisition activity between renewable energy firms is not included.

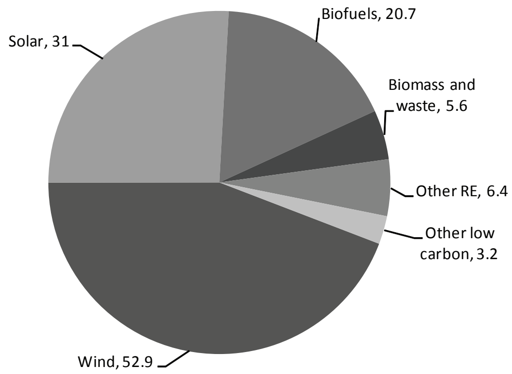
15 New Energy Finance, 2008: A Year of Two Halves for Clean Energy Investment, 14 January 2009. Available at <www.newenergymatters.com/?p=about&n=13>.

16 See WilderHill New Energy Global Innovation Index (NEX) website at <www.nexindex.com>.

over the sustainability of feedstocks. Wind power shares fell by 56 per cent driven by concerns over ongoing availability of project financing.[17]

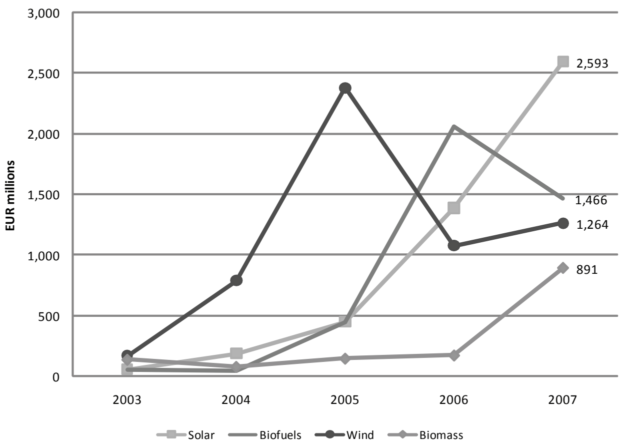
The three technologies in which VC and PE firms were most active from 2003 to 2008 were solar, biofuels and wind, which were collectively responsible for 69 per cent of total VC and PE investment in the RE sector in 2008.[18] Of the RE technologies, solar PV has seen the fastest growth in VC and PE investment in recent years (see Figure 2.4).[19] Equally, public market investment and asset finance of solar PV manufacturing capacity and solar parks has grown over the last few years. Recently however, this too has fallen as a result of the financial crisis and global economic downturn.

**Figure 2.3: Global new third-party investment in renewable energy by technology in 2008 (USD billions): Total USD 121 billion**




Source: International Energy Agency, The Impact of the Financial and Economic Crisis on Global Energy Investment, May 2009. Available at <iea.org/textbase/Papers/2009/G8_FinCrisis_Impact.pdf>.

**Figure 2.4: Growth in global VC and PE renewable energy investment by selected technology**




Source: Derived from New Energy Finance and the United Nations Environment Programme (UNEP), Global Trends in Sustainable Energy Investment 2008 – Dataset, July 2008. Available at <sefi.unep.org/fileadmin/media/sefi/docs/publications/data_2008.pdf>.

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17 New Energy Finance, Clean Energy Shares Take a 61% Battering in 2008 – With Solar and Biofuels the Worst Hit Sectors, 7 January 2009. Available at <www.nexindex.com>.

18 Figures are based on disclosed deals and include private equity buyouts, private investment in public equity and investor exits through over the counter market offerings.

19 New Energy Finance and the United Nations Environment Programme (UNEP), Global Trends in Sustainable Energy Investment 2008 – Dataset, July 2008. Available at <sefi.unep.org/fileadmin/media/sefi/docs/publications/data_2008.pdf>.

### *2.1.1.3. Solar Merger and Acquisition Activity in 2008*

There has been considerable merger and acquisition (M&A) activity in the solar power sector in the last few years. As detailed in Table 2.2, European M&A activity in the solar power sector in 2008 was valued at over EUR 2 billion.

**Table 2.2: Mergers and acquisitions in the European solar power market in 2008**

| Month | Value (EUR million) | Target for Merger | Country Target Based In | Acquirer |
|---|---|---|---|---|
| January | 19.6 | Gallivare PhotoVoltaic (65%) | Sweden | Borevind AB |
| February-September | 107 | Six solar power plants | Germany | Renewagy AS |
| April | 261 | Gamesa Solar | Spain | First Reserve |
| April | 87 | Six solar power plants in Spain from SOLON AG | Spain | Meinl International Power Limited |
| May | 30 | Three solar power plants | Spain | AIG |
| May | 7.6 | Scatec AS (10%) | Norway | Itochu Corp. |
| June | 546.4 | Ersol Solar Energy AG | Germany | The Bosch Group |
| June | 14 | G24 Innovations Ltd. (Stake %) | UK | Morgan Stanley Principal Investments |
| June | 2.6 | Helio Dynamics Ltd. (70%) | UK | Energy Mixx AG |
| July | 21 | G24 Innovations Ltd. (Stake %) | UK | 4RAE |
| July | 85 | SULFURCELL Solartechnik GmbH | Germany | Intel Corp and other private equity companies |
| July | 150 | Isofoton SA (26%) | Spain | Grupo Berge Diversified |
| August | 190 | OLIVENTO SLU (owned by Babcock and Brown) | Spain | Formentode Construccionesy Contratas SA |
| August | 5.6 | TerniEnergia SpA (26.52%) | Italy | Market Purchase |
| September | 140 | Two solar power stations from Sky Global SA | Spain | Fomentode Construccionesy Contratas SA-FCC |
| September | 137 | Three solar power plants | Spain | Sunray Renewable Energy |
| September | Not disclosed | Four solar power plants from GA Solar | Spain | Fotowatio Energia Solar SL |
| November | 90 | Renewagy AS | Denmark | Colexon Energy AG |
| November | 70 | Solar power plants in Spain from Systaic | Spain | Eurovoltaic plc |
| November | 12 | ALGATEC Solar AG | Germany | Solar Thin Films Inc. |
| December | 30 | Helios Technologies Srl (part owned by Kerself SpA) | Italy | Immobiliare Ve Ga S.p.A |
| December | 6 | Johanna Solar Technology GmbH (11.8%) | Germany | Sunvim Group Co. Ltd. |

Source: Derived from information available on the companies’ websites.

Given the shortage of available finance through the capital markets and private and institutional investors in late 2008 and 2009, it is likely that of the various types of investment in the solar PV sector, M&A will fare the best and possibly accelerate, as smaller or more heavily leveraged firms seek new parent firms with greater financial reserves in order to weather the financial crisis.

### 2.1.2. Concentrated Solar-thermal Power (CSP) Technology

Concentrated solar-thermal power (CSP) plants are highly capital intensive and require large, flat areas with high irradiation levels. At the end of 2008, the total global installed capacity of CSP was 431 MW. Almost all of it, 97 per cent, was located in the US with the remaining 3 per cent in Europe, predominantly in Spain, with a few small test facilities in France and Germany.

The European Commission has stated that it believes that CSP can play an important part in meeting the EU's 2020 renewable energy target. The European Solar Thermal Electricity Association (ESTELA) projects that by 2020 Europe could have 30 GW of installed capacity generating 85 TWh of electricity a year, rising to 60 GW generating 175 TWh a year by 2030. ESTELA is also advocating the construction of large CSP plants in North Africa linked to Europe through high voltage transmission lines.

There are three main technologies that are used in CSP plants. They are:

- Trough plants (Parabolic and Fresnel)
- Central receiver/tower plants
- Dish-stirling plants.

The only technologies that are commercially operating as of January 2009 are trough and central receiver plants (see Table 2.3). Of these, the trough technology is more widely used for grid-connected applications. For plants of both of these types, biomass and natural gas can be used as a backup power source. Fresnel troughs are less expensive to build compared to regular parabolic troughs, however, the operating system used is the same in both. Dish-stirling plants are currently only used for microgeneration, although there are plans in the United States to expand their use.

**Table 2.3: Comparison of trough and central receiver/tower systems**

| Technology | Overview | Advantages | Disadvantages |
|---|---|---|---|
| Parabolic trough / Fresnel trough | Rows of mirrors concentrate the sunlight on a liquid-filled tube. The heated liquid is then used to turn a turbine. Some systems can store heat. | Requires less land and material for production than other forms of CSP. | Current systems can only operate at 400C due to the oil-based liquid used. This reduces its potential operating efficiency. If higher temperatures could be used then efficiency could be increased. |
| Central receiver/ tower | Mirrors reflect the sunlight onto a tower where the heat is stored and then used to produce steam to generate electricity using a turbine. | Potential to operate at temperatures beyond 1,000C, which will significantly increase efficiency (565C proven). | A relatively unproven technology. |

Source: Derived from European Solar Thermal Industry Association and Greenpeace, Concentrated Solar Thermal Power – Now! September 2005. Available at <www.estelasolar.eu/fileadmin/ESTELAdocs/documents/OPUS_-_Concentrated-Solar-Thermal-Power-Plants-2005.pdf>.

Power conversion efficiency for CSP technologies is approximately 16 to 20 per cent (in other words, 16 to 20 per cent of the energy received from the sun is converted into electricity), but as higher operating temperatures are reached, electricity generating efficiency will improve.

For all CSP technologies, achieving temperatures in excess of 700 to 800 degrees Celsius is required to maximise efficiency in operation and energy storage; however, this has not been attained and more research and development into materials and technology will be required in order to do so.[20]

Power conversion efficiency for CSP technologies is approximately 16 to 20 per cent (in other words, 16 to 20 per cent of the energy received from the sun is converted into electricity), but as higher operating temperatures are reached, electricity generating efficiency will improve.[21]

The current levelised generation cost of CSP in areas with 2,100 kWh/$m^2$ of solar irradiation a year, such as in southern Spain, Portugal, Italy, France and Greece, is around 270 EUR/MWh. The total cost of building and operating CSP plants is expected to decline at an annual rate of 3 per cent from 2012 as more expertise is developed.[22]

There are five CSP plants operating in Europe as of May 2009 (see Table 2.4), and more than 10, mostly parabolic troughs, are in advanced stages of development. The majority of these plants are located in southern Spain which is understandable given the high level of solar irradiation in that region. In Spain, a total of 6,000 MW of projects were registered and were in various stages of planning as of the beginning of 2008.[23]

**Table 2.4: Concentrated solar power plants in operation in Europe**

| Country | Name | Location | Developer | Size | Date of Ooperation | Notes |
|---|---|---|---|---|---|---|
| Spain | PS10 | Sevilla | Abengoa Solar | 11 MW | 2006 | The first commercial CSP tower project in the world. |
| | PS20 | | | 20 MW | April 2009 | Features a number of technological improvements on PS10, including high-efficiency receivers and improved energy storage. |
| | Andasol I | Guadix, Granada | Solar Millenium | 50 MW | November 2008 | The first commercial parabolic trough power plant in Europe. Two more 50 MW plants are under constructution next to Andasol I. |
| | Ciudad Real | Puertollano | Iberdrola | 50 MW | May 2009 | A parabolic trough plant with the potential to generate 100 GWh per year. |
| | PE1 | Murcia | Novatec BioSol AG | 1.4 MW | April 2009 | First commercial Fresnel trough plant in Europe. |

Source: Information from developers' websites.

20 Join Research Council, Workshop Report on CSP Technology, 29 May 2007. Available at <ec.europa.eu/energy/res/setplan/doc/csp_workshop/workshop_report_csp_final.pdf>.

21 European Solar Thermal Electricity Association, Solar Thermal Electricity, May 28 2008. Available at <www.estelasolar.eu/fileadmin/ESTELAdocs/documents/2008.05.28_ESTELA_DisseminationDocFull.pdf>.

22 Jackie Jones, 'Concentrating Solar Thermal Power,' Renewable Energy World, 2 September 2008. Available at <www.renewableenergyworld.com/rea/news/story?id=53473>.

23 European Solar Thermal Electricity Association, Solar Thermal Electricity, May 28 2008. Available at <www.estelasolar.eu/fileadmin/ESTELAdocs/documents/2008.05.28_ESTELA_DisseminationDocFull.pdf>.

## 2.2. Incentives for Solar PV Power Development in the EU

Analysts are generally agreed that government incentives are the key factors that drive growth in the grid-connected solar PV sector.[24] As long as solar power technology remains both financially non-viable and strategically important as a clean and renewable power source, governments will be required to support its development. The role of government incentives in promoting the deployment of renewable electricity is best demonstrated in the EU, which has, through different incentive schemes adopted by its individual member states, become the global leader in installed solar power capacity.

There are a range of incentives offered by different EU governments. The primary incentives offered in the EU are operating incentives, in other words, support per MWh of electricity produced. Generally three schemes are used in EU member states for providing operating incentives:

- Feed-in tariffs (FITs)
- Fixed and variable premiums[25]
- Tradable green certificates (TGCs).

### 2.2.1. Feed-in Tariff (FIT)

A FIT system is an electricity generation incentive in the form of a fixed price and guaranteed buyer of renewable electricity. It requires electricity network operators to purchase all the output renewable electricity generators supply to the grid at a set price regardless of whether or not the output is needed to satisfy demand at the time. This is known as "obligatory purchase". The price levels and duration of each FIT vary among countries and are specific to each renewable power technology employed. In some member states, generators can receive the FIT even for electricity that they consume and which is not supplied to grid.

While a FIT rate is generally guaranteed to a generator for a period of time from the date of its first connection to the grid, the FIT rates offered to any generator making a new connection to the grid are subject to adjustments over time. In some countries the rates are periodically re-evaluated, while in others they are constant for a period and thereafter lowered at a predetermined annual rate, which is termed a degression rate. In both instances, these adjustments seek to correlate more accurately the tariff rate with the projected declines in generation cost as renewable electricity generation technologies mature.

The FIT system is considered a relatively good incentive for driving investment in renewable development as it offers a degree of predictability to revenue through the predetermined price and a guaranteed buyer. This appears to be borne out by recent trends in the EU where the largest growth in renewable electricity investment and development has occurred in countries using FITs as the primary support system.

The FIT incentive system is, however, seen as less market-oriented than other incentive schemes as it shields renewable electricity generators from the variability of the open wholesale electricity market. As the grid operators are obliged to take all renewable electricity generated, there is some concern about the effect of large amounts of non-dispatchable renewable power on the grid.

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24 Electronics Design, Strategy, News, 'Solar's Bright Future,' 15 December 2008. Available at <edn.com/article/CA6622867.html?industryid=48883>.

25 Sometimes called "green bonuses". In EU documents premiums are generally considered a form of feed-in tariff. However, it is important to note the differences. See below.

### 2.2.2. Premium

A variation on the FIT model is the premium incentive, also known as the green bonus scheme. Under a premium system, generators sell their output on wholesale electricity markets like any other generator, without the purchase obligation offered by the FIT. Under the premium system generators are entitled to receive a supplementary amount, or "premium", in addition to the market price of electricity for every MWh of electricity they sell. This is paid by the relevant government agency or network operator, who in turn recovers it through a tax on electricity sales or from the government's general budget.

There are two types of premiums, fixed and variable. Under a fixed premium, the generator receives a set amount for each unit of output sold on the open market regardless of the market price of electricity. With a variable premium, the generator receives a variable amount, calculated as the difference between the market price at the time of sale and a predetermined higher price generally set by a government agency. To illustrate the difference between fixed and variable premiums, hypothetical examples of both types of premium are provided below.

Under the fixed premium system, a spot market electricity price at a point in time of 55 EUR/MWh and a fixed premium of 33 EUR/MWh provides a generation compensation of 88 EUR/MWh. If the market price falls to 45 EUR/MWh, the fixed premium remains 33 EUR/MWh and hence the generation compensation drops to 78 EUR/MWh. Under the variable premium system, if the predetermined guaranteed price is 88 EUR/MWh, and should the market price then fall from 55 EUR/MWh to 45 EUR/MWh, the premium is adjusted from 33 EUR/MWh to 43 EUR/MWh to compensate for this drop. If there was an increase in the wholesale electricity price to 60 EUR/MWh, under the fixed premium, generation compensation would increase to 93 EUR/MWh made up of the 60 EUR/MWh price of electricity plus the fixed 33 EUR/MWh premium. Under the variable premium system, the premium would fall to 28 EUR/MWh to maintain the generation compensation at 88 EUR/MWh.

### 2.2.3. Tradable Green Certificates (TGC)

Under a TGC incentive system, renewable electricity generators sell their output on the wholesale market at the same prices and under identical conditions as all other electricity generators. For every MWh of renewable electricity supplied to the market, one TGC is awarded to the relevant renewable electricity generator.[26] This TGC can then be sold by the generator to a supplier or distributor, either directly or through an independent TGC market. Demand for the TGCs is created through a quota obligation, whereby electricity suppliers or distributors are obliged to present a set number of TGCs to the regulator every year. If suppliers fall short of their quota obligations, they are required to pay a penalty per outstanding TGC. In some TGC systems, certificates can be banked for use in later periods.

The TGC system is generally considered more market-driven than other systems because generators are active in two parallel markets, the open electricity market where renewable electricity is sold, and the TGC market where the TGCs are sold. Given the fact that both of these market prices are determined by supply and demand, the need for generators to improve operational efficiency and, in the longer term, align their generation costs to those of non-renewable electricity providers is more acute than it is in other incentive systems.

26 A range of green certificates are issued in different EU member states which are not tied to quota obligations and are not traded on the TGC market as described in this report. These certificates serve solely as proof of origin for renewable electricity and are not considered a primary operating support incentive as these certificates are purchased voluntarily for various reasons, including public relations benefit and marketing, and hence provide no guarantee for renewable electricity developers.

There are, however, concerns regarding the TGC system. One of them is that the TGC system generally makes no distinction between more established renewable electricity technologies with comparatively low generation costs, and emerging technologies with generally higher generation costs. Thus, generally only mature and established technologies can be supported and the ability of the TGC system to promote broader renewable electricity generation development is therefore limited. In some countries there is a system known as "technology banding" where some technologies, such as solar PV, receive a greater number of TGCs for each MWh supplied than more established, and cheaper, technologies such as landfill gas.

Another concern relates to the stability of the TGC market. In the short-to-medium term, the TGC system relies on demand for TGCs, created by the quota system, to drive their market price to a point at which their sale by renewable electricity generators can adequately cover the relatively high generation cost of renewable electricity. Should the TGC quota obligations on electricity suppliers or distributors be too low, the TGC price could collapse as TGC supply would exceed demand, and so undermine the support for renewable electricity generation. This susceptibility to fluctuations in two markets creates a considerable long-term investment risk.[27]

To reduce this risk, some TGC schemes, such as those found in Belgium and Italy, provide a support mechanism for the TGC market in the form of a "market maker". Generally, the market maker is established and supported by the country's transmission system operator (TSO) and it commits to buying and selling TGCs at a minimum or "reference" price. This removes the risk of a TGC market collapse. In practice, with the exception of a few emerging renewable electricity technologies, this minimum price maintained by a market maker falls below the average open-market TGC price.

### 2.2.4. Solar PV Incentives in Europe

According to solar developers, and as demonstrated in the statistics, those countries that have FITs have shown much faster development of their solar power sectors than those countries that use one of the other schemes.[28] The European Commission has also stated that FITs are more effective than TGCs as a way to promote the deployment of renewable electricity.[29]

Although most of the countries that have seen rapid solar power development use FITs, the specific FIT rates vary greatly. Some generalisations can however be made. Most countries give higher incentives to smaller capacity and building-integrated PV (BIPV) than to large-scale, ground based solar PV installations. For example, Spain recently changed its incentive system as a way to encourage small-scale development in order to encourage local employment and local industry.[30]

The following are descriptions of the operating incentive schemes in the seven European countries that have seen the fastest recent growth in solar PV deployment.[31] In addition to these operating incentives, most governments offer investment subsidies for the purchase and installation of solar PV systems. These subsidies vary greatly but are generally aimed at households and small businesses.

27 Robert Gross, Philip Heptonstall, and William Blyth, Investment in Electricity Generation: The Role of Costs, Incentives and Risks, UKERC, May 2007. Available at <www.ukerc.ac.uk/Downloads/PDF/07/0705TPAInvestmentReport/0705InvestmentReport.pdf>.

28 Interview with the European Photovoltaic Industry Association.

29 Commission of the European Communities, Communication from the Commission: The Support of Electricity from Renewable Energy Sources, December 2005. Available at <europa.eu/scadplus/leg/en/lvb/l27035.htm>.

30 Interview with EPIA, November 2008.

31 For more detailed information on the incentive schemes in each country, see London Research International's *The European Renewable Electricity Sector 2009-2010.*

### 2.2.4.1. *Germany*

Germany is the dominant market for solar power in Europe and it uses FITs. German FIT rates are guaranteed for 20 years, therefore a renewable electricity generating installation in Germany receives a set FIT rate per MWh of output it generates for 20 years after first connection to the grid. In 2010, the FIT rates available to renewable electricity generators making new connections to the grid in Germany will be decreased by between 8 and 10 per cent, and then by 9 per cent for every subsequent year to reflect decreasing generation costs. These are termed degression rates (see Table 2.5).

**Table 2.5: Feed-in tariffs in Germany for solar PV for 2009, 2010 and 2011 (EUR/MWh)**

| Category | | 2009 FIT Rate (EUR/ MWh) | Applied Degression Rate | 2010 FIT Rate (EUR/ MWh) | Applied Degression Rate | 2011 FIT Rate (EUR/ MWh) |
|---|---|---|---|---|---|---|
| Building-integrated PV | Up to 0.03 MW | 430.1 | 8% | 395.7 | 9% | 360.1 |
| | 0.03-0.1 MW | 409.1 | 8% | 376.4 | 9% | 342.5 |
| | 0.1-1 MW | 395.8 | 10% | 356.2 | 9% | 324.2 |
| | > 1 MW | 330 | 10% | 297 | 9% | 270.3 |
| Ground based | | 319.4 | 10% | 287.5 | 9% | 261.6 |

Source: BMU, EEG – The Renewable Energy Sources Act (2009). Available at <www.erneuerbare-energien.de/files/pdfs/allgemein/application/pdf/eeg_2009_en.pdf>.

### 2.2.4.2. *France*

**Table 2.6: Feed-in tariff rates in France for solar PV in 2009**

| Location | Category | FIT Rates (EUR/MWh) |
|---|---|---|
| Metropolitan France | BIPV | 572 |
| | Commercial buildings (rooftops) | 450 |
| | Other (including ground-based systems) | 328 |
| Corsica and overseas departments | BIPV | 602 |
| | Other | 437 |

Source: Ministere de l'economie de'industrie et de l'emploit, 'Les tariffs d'achat de l'électricité produite par les énergies renouvelables et la cogénération.' Available at <www.industrie.gouv.fr/energie/renou/f1e_ren.htm>; Enerplan, L'actualite de solar, June 2008. Available at <www.enerplan.asso.fr/index.php?option=com_content&task=view&id=234&Itemid=203>. 'France Raises Solar PV Tariff,' Renewable Energy World, 21 November 2008. Aailable at <www.renewableenergyworld.com/rea/news/story?id=54119>.

In 2008, the French government revised its FIT for solar PV. The previous FIT system, which only had two categories, that is, for small building-integrated PV (BIPV) and others, was criticised because rooftop PV installations other than BIPV were included in the latter without giving sufficient incentives.[32] To encourage large commercial buildings such as factories to install medium and large-scale rooftop systems, in November 2008 the government introduced a special 450 EUR/MWh tariff targeted at this market.[33] The FIT rates introduced in 2008 are valid for 20 years and are exceptionally attractive for BIPV installations (see Table 2.6). BIPV

32 Eric Laborde, The French PV Market: Recommendations for a Fast Development, Presentation by Photowatt, 27 June 2008. Available at <www.epia.org/fileadmin/EPIA_docs/documents/AGM/French_Symposium/Session_1_-_1-Eric_Laborde_French_PV_Market_EPIA_June_27_2008.pdf>.

33 'France Raises Solar PV Tariff,' Renewable Energy World, 21 November 2008. Available at <www.renewableenergyworld.com/rea/news/story?id=54119>.

is defined as the integration of photovoltaic modules into the envelope of a building, such as the roof or façade.[34] The government has published a technical guide to indicate which forms of BIPV are eligible for the increased tariff. The guidelines are very specific and vary greatly depending on the type of building, location and its uses.[35]

### 2.2.4.3. *Spain*

In Spain, both FITs and premiums are offered for most renewable electricity generation. However, for solar PV generators only a FIT is offered. A new FIT was introduced on 29 September 2008 as a result of a faster than expected expansion of the Spanish solar PV market and resultant drain on the budget.[36] The new Spanish FIT is geared towards promoting the deployment of building-integrated PV (BIPV) and small-scale residential solar PV installations over ground-based installations. Smaller installations tend to create local employment as they are usually installed by local contractors and not by large foreign companies.[37] For solar power, there is a yearly capacity cap of new solar power installations that will qualify for the FIT system. In 2009, 500 MW of new installations will be allowed into the special regime for FIT incentives. The capacity caps will decline for large ground-based installations in the coming years, and the cap for smaller BIPV installations will increase. Table 2.7 shows the FIT rates for solar PV in Spain after 29 September 2008 and the annual capacity caps until 2011.

**Table 2.7: Feed-in tariff rates in Spain for solar PV for installations commissioned from 29 September 2009**

| Category | | FIT Rates (EUR/MWh) | Duration | Capacity Cap in 2009 (MW) | Capacity Cap in 2010 (MW) | Capacity Cap in 2011 (MW) |
|---|---|---|---|---|---|---|
| Type 1 (BIPV) | Type 1.1: ≤20 kW | 340 | 25 years | 27 | 30 | 33 |
| | Type 1.2: >20 kW | 320 | 25 years | 240 | 265 | 292 |
| Type 2 (Other) | Up to 50 MW | 320 | 25 years | 233 | 207 | 162 |

Source: Real Decreto 1578/2008, de 26 de septiembre 2008 de retribución de la actividad de producción de energía eléctrica mediante tecnología solar fotovoltaica para instalaciones posteriors a la fecha límite de mantenimiento de la retribución del Real Decreto 661/2007, de 25 de mayo, para dicha tecnología. Available at <www.cne.es/cne/doc/legislacion/RD-fotovoltaica-Sept08.pdf>.

### 2.2.4.4. *Portugal*

Portugal uses a feed-in tariff (FIT) system as its primary incentive for renewable electricity development. The FIT was originally introduced in 1998 and the current scheme was revised for installations commissioned from 2008 onwards. There are special incentives for microgeneration up to 3.68 kW where electricity and heat is produced at the same installations. For all technologies, there is a total national capacity cap. Once that capacity cap is reached, new installations will not be compensated through the incentive system. Table 2.8 shows the FIT rates in Portugal for new installations commissioned in 2009.

34 WBDG, Building Integrated Photovoltaics. Available at <www.wbdg.org/resources/bipv.php>.
35 The technical guide is available at <www.industrie.gouv.fr/energie/electric/pdf/guide-integration.pdf>.
36 In Spain, tariff increases for entire segments of the market are controlled by the government. Under the government-controlled tariff system, the government has to bear partially or fully the cost increases associated with government incentives.
37 Interview with representative from the European Photovoltaic Industry Association.

**Table 2.8: Feed-in tariff rates in Portugal for installations commissioned in 2009**

| Category | | Average FIT Rate (EUR/MWh) | Duration | Capacity Cap |
|---|---|---|---|---|
| Solar PV | ≤ 5 kW | 520 | 15 years or first 21 GWh/MW | 150 MW |
| | > 5 kW | 350 | | |
| Building-integrated solar PV | ≤ 5 kW | 550 | 15 years | 50 MW |
| | 5-150 kW | 400 | | |
| Solar PV when combined with heat production | ≤ 3.68 kW | 650 | 15 years | 10 MW |

Source: Ministry of Economy and Innovation, Decreto-Lei n.o 225/2007 de 31 de Maio 2007. Available at <www.iapmei.pt/iapmei-leg-03.php?lei=5499>; Ministry of Economy and Innovation,Decreto-Lei n.o 363/2007 de 2 de Novembro 2007. Available at <www.garanova.com/garanova/legislacao_files/DL 363.2007.pdf>.

### 2.2.4.5. *Italy*

For most renewable electricity generation in Italy a TGC system is used as the primary operating incentive. However, the Italian government offers feed-in tariffs (FIT) for solar PV and for microgeneration (up to 1 MW). In 2005, Italy introduced a special FIT system for solar PV. The Italian solar PV FIT was revised in 2007 to promote PV development more effectively, and BIPV in particular (see Table 2.9). The FIT rates are valid for 20 years and an annual 2 per cent degression rate will be applied for facilities installed in subsequent years.[38]

The FIT regime will be available until a total of 1,200 MW of solar power has been installed, and the FIT rates may be revised in 2010 to take into account the growth rates needed for Italy to meet its 3 GW solar PV target. There is neither an annual cap nor any limit on plant size. For residential installations, the FIT rates can also be increased by 10 to 30 per cent if proof of energy efficiency (such as extra insulation) can be shown. Another 5 per cent bonus is added if the producer is a school, hospital or other public-sector establishment or if the replacement of an asbestos roof is included at the time the roof-topped PV panels are installed. For installations under 20 kW, consumers can receive an extra bonus for electricity supplied to the grid if they have net metering.[39]

**Table 2.9: Feed-in tariff rates in Italy for systems installed before December 2009 (EUR/MWh)**

| Category | | FIT Rates (EUR/MWh) |
|---|---|---|
| Ground-mounted | 1 | ` |
| | 3–20 kW | 372 |
| | >20 kW | 353 |
| Building-attached solar PV (BAPV) | 1–3 kW | 431 |
| | 3–20 kW | 412 |
| | >20 kW | 392 |
| Building-integrated (BIPV) | 1–3 kW | 480 |
| | 3–20 kW | 451 |
| | >20 kW | 431 |

Source: GSE, Nuovo Conto Energia. Available at <www.gse.it/attivita/ContoEnergiaF/servizi/Pagine/NuovoContoEnergia.asp>.

38 GSE, Incentivazione degli impianti fotovoltaici. Relazione delle attivita' – Ottobre 2006-Settembre 2007. Available at <www.gsel.it/ita/pubblicazioni/20080110_RapportoFTV2007.pdf>.

39 Salvatore Castello, Anna De Lillo, et al. National Survey Report on PV Power Applications in Italy 2007, May 2008. Available at <www.iea-pvps.org/countries/download/nsr07/NSR IT 2007.pdf>.

### 2.2.4.6. *Czech Republic*

The Czech Republic adopted a feed-in tariff (FIT) system as its primary support mechanism for renewable electricity development in 2002. In 2005, the government introduced a new incentive system offering renewable electricity generators the choice between a FIT and a fixed premium. Table 2.10 shows both the FIT rates and the fixed premiums for solar PV installations in the Czech Republic in 2009.

Renewable electricity generators have to choose between these two incentive schemes on an annual basis as mid-year switching is prohibited. For the FIT, the developer needs to conclude a purchase agreement with a grid operator. To receive the premium, the developer needs to conclude a purchase agreement with a grid operator or supplier. The prices received under the FIT system are guaranteed for the entire duration of the programme The premium the developer receives will vary every year depending on the price of electricity and other factors, as decided by the energy regulatory office (*Energetický regulační úřad, ERU*), however, annual adjustments to the rates are limited to 5 per cent below the preceding year.[40]

**Table 2.10: FIT rates and fixed premiums in the Czech Republic for projects commissioned after 1 January 2009**

| Category | | FIT Rates | | Fixed Premium | | Duration (years) |
|---|---|---|---|---|---|---|
| | | CZK/MWh | EUR/MWh | CZK/MWh | EUR/MWh | |
| Solar PV | ≤30 kW | 12,890 | 515.81 | 11,910 | 476.59 | 20 |
| | >30 kW | 12,790 | 511.80 | 11,810 | 472.59 | |

Note: All exchange rates in this report are based on the 2008 average EUR-CZK rate of EUR1 = CZK24.99.
Source: The Energy Regulatory Office's Price Decision No. 8/2008 of 18 November 2008 Laying Down Support for Electricity Generation from Renewable Energy Sources, Combined Heat and Power, and Secondary Energy Sources. Available at <www.eru.cz/user_data/files/english/Price decision/CR8_2008en.pdf>.

### 2.2.4.7. *Greece*

A feed-in tariff (FIT) system was first introduced in Greece in 1994 and was last revised in 2009. There are currently two sets of tariff rates, one for the installations on the mainland and those islands that are interconnected with the mainland grid, and one for islands that are not interconnected with the mainland grid system (see Table 2.11). Starting in 2010, there will be a 1 per cent degression per month for new entrants, until 2013, when the degression rate will be 0.5 per cent. In 2009, the government introduced a special FIT rate for building-integrated PV (BIPV). The BIPV FIT rate is 550 EUR/MWh for a system producing up to 10 kW and is valid for 25 years. A degression rate of 5 per cent for the BIPV FIT is expected to apply from 2012.[41]

The local grid network operator is obliged to enter a 10-year purchase agreement with the renewable electricity generator through which the FIT is guaranteed for all output. This agreement can be extended by another 10 years if the producer so decides. All renewable electricity output has to be taken into the grid. The FIT rates can be adjusted annually at a rate based on 80 per cent of the consumer price index as calculated by the Bank of Greece.[42]

40 Salvatore Castello, Anna De Lillo, et al. National Survey Report on PV Power Applications in Italy 2007, May 2008. Available at <www.iea-pvps.org/countries/download/nsr07/NSR IT 2007.pdf>.
41 Hellenic Association of Photovoltaic Companies, New Incentive for Small Rooftops, June 2008. Available at <www.helapco.gr/library/8_6_09/New_incentives_for_rooftop_PV_in_Greece.pdf>.
42 Ministry of Development, Law 3468/2006: Generation of Electricity using Renewable Energy Sources and High-Efficiency Cogeneration of Electricity and Heat and Miscellaneous Provisions. Available at <www.ypan.gr>.

**Table 2.11: Greek FIT rates for new solar PV installations in 2009 (EUR/MWh)**

| Category | | FIT rates for Mainland and Interconnected Islands | FIT rates for Non-Interconnected Islands |
|---|---|---|---|
| Solar PV | ≤100 kW | 450 | 500 |
| | >100 kW | 400 | 450 |
| | BIPV ≤10 kW | 550 | 550 |

Source: Ministry of Development, Law 3468/2006: Generation of Electricity using Renewable Energy Sources and High-Efficiency Cogeneration of Electricity and Heat and Miscellaneous Provisions. Available at <www.ypan.gr>; Ministry of Development, Law 3473/2009. Available at <www.ypan.gr>.

### *2.2.4.8. Belgium*

Since the 2002-2003 fiscal year (1 April to 31 March), Belgium has been using a tradable green certificate (TGC) system as its primary support mechanism. Although TGCs are used nationwide, the system is implemented differently in the regions, with prices and certain conditions varying between them. There are four TGCs in Belgium, although as Wallonia and Flanders are the largest regions, their TGC systems are the most important:

- The Federal green certificate
- The Flanders green certificate
- The Wallonia green certificate
- The Brussels green certificate.

Unlike most other countries that have a TGC system, Belgium offers a minimum price alternative as well, banded to provide different minimum prices to different renewable electricity generation technologies. Instead of selling TGCs on the open market only, the minimum price guarantee allows renewable electricity generators to sell their TGCs directly to Elia (the federal transmission system operator, or TSO, that operates in all the regions) at a regionally specific, government-set minimum price. These TGCs are then sold back into the open TGC market by the TSO. The minimum price alternative provides compensation for solar PV generation. In effect, solar PV generators receive income from two separate streams: the sale of their electricity on the wholesale market, and the sale of their TGCs to the grid operator.

**Table 2.12: The application of technology banding in Wallonia with the minimum purchase price**

| Category | | Technology Banding (TGC per MWh) | Minimum Price Guarantee under Technology Banding (EUR/MWh)[a] | Theoretical Maximum Price (EUR/MWh)[b] |
|---|---|---|---|---|
| Solar PV | 0-5 kW | 7 | 455 | 700 |
| | 5-7 kW | 5 | 325 | 500 |
| | > 7 kW[c] | 1 | 150[c] | 150[c] |

Notes: [a] Based on minimum price of EUR 65 per certificate and the technology banding.
[b]As the penalty is EUR 100, it is assumed that the ceiling price of the certificate is EUR 100.
[c]Above 7 kW technology banding is not applied to solar PV and the certificates are purchased by Elia at EUR 150.
Source: CWaPE, Rapport Annuel Specfifique 2007 'l'évolution du marché des certificats verts', June 2008. Available at <www.cwape.be/servlet/Repository?IDR=10695>.

In Flanders, solar PV generators can sell their TGCs to Elia for 450 EUR/MWh. This price is guaranteed for 20 years and is on top of the income solar PV generators receive from selling their output. In Wallonia, the system is different. In that region, all renewable electricity generators can sell their certificates to the grid operator for 65 EUR/MWh, but technology banding, in other words the awarding of more TGCs for each MWh based on technology, provides additional support for solar PV generation (see Table 2.12). Solar PV installations over 7 kW do not receive additional support under the regional technology banding, but generators can sell their TGCs to the Federal grid operator Elia. The return however, is not as high as that found under the regional incentives. The TGC system in Wallonia is guaranteed for 15 years and generators also receive income from the sale of their electricity in addition to the sale of the TGCs.

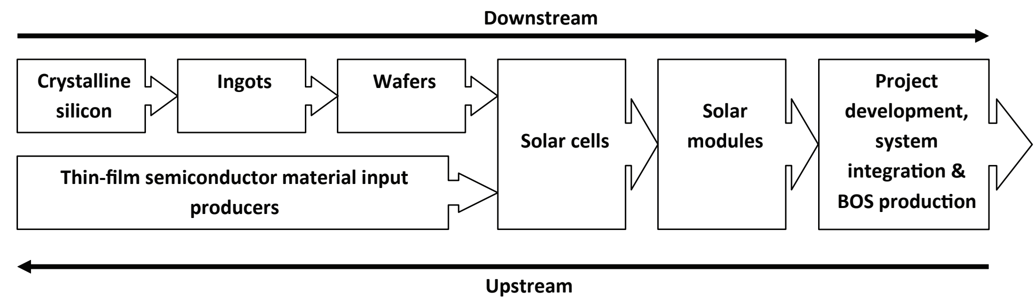
# Chapter 3: Solar PV Industry Analysis

## 3.1. Solar PV Value Chain Overview

An analysis of the solar PV sector requires a clear understanding of the industry's value chain. Within a single business unit, the value chain refers to the primary line functions or processes: from inbound logistics, through operations, to outbound logistics, marketing, sales and finally ongoing service and maintenance.[43] On an industry level, the value chain involves the multi-stage transformation of a raw material into an installed and operational finished product.[44] In most industries, this involves both specialist firms, active at a single stage of a value chain, as well as integrated firms, which have control over multiple stages of the value chain.

The solar PV value chain involves the multi-stage manufacturing, assembly and ultimate installation of solar modules as functional electricity generating systems. The crystalline silicon solar cell-based value chain begins with the production of high purity silicon which is cast into square ingots using molten silicon, pulled into string ribbons, or grown into crystalline ingot rods. Ingot blocks, rods or ribbons are then sliced into extremely fine silicon wafers, which are in turn used to manufacture solar cells using a complicated and capital-intensive process. Multiple solar cells are then combined to form functioning solar modules which can then be installed for electricity generation, either individually or in multiple-module systems, using a range of installation materials collectively termed the "balance of system" (BOS)[45] (see Figure 3.1).[46]

**Figure 3.1: The solar PV value chain**




### 3.1.1. Crystalline Silicon

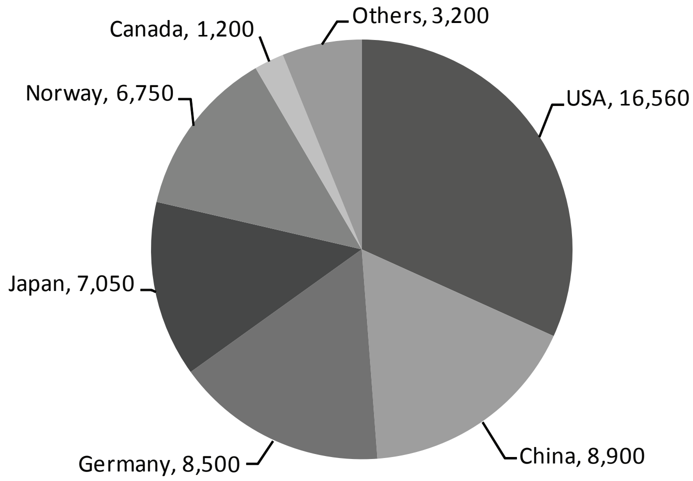
Crystalline silicon is the feedstock material for wafer-based solar modules. The production of silicon for industrial use involves the refinement of silicon into either polycrystalline silicon, a common input for the solar PV industry, or higher purity monocrystalline silicon predominantly used in the manufacture of microprocessors and electronics.

#### *3.1.1.1. Global Silicon Output*

In 2007, worldwide polysilicon production capacity was approximately 52,000 tonnes.[47] Production is broken down by country in Figure 3.2.

43 12 Manage, Vertical Integration. Available at <www.12manage.com/methods_vertical_integration.html>.
44 MAW, Value Chain Analysis. Available at <maaw.info/ArticleSummaries/ArtSumDonelanKaplan98.htm>.
45 PhotoVoltaic Technology Platform, A Strategic Research Agenda for Photovoltaic Solar Energy Technology, 2007. Available at <cordis.europa.eu/technology-platforms/pdf/photovoltaics.pdf>.
46 Given that the market is dominated by crystalline silicon material and producers of most thin-film solar modules are also large producers of crystalline silicon modules, the two industry value chains have been combined in this stylised outline.
47 Yole Development, Photovoltaic Report: Technology, Equipment and Materials. Available at <www.yole.fr>.

**Figure 3.2: Global polysilicon production capacity by country in 2007 (tonnes)**




Source: Yole Development Photovoltaic Report, 2008. Available at <yole.fr/pagesAn/products/Report_sample/Yole_PV_Technology_Equipment_and_Materials_2008_Report_Sample.pdf>.

Between 2004 and 2008, the global demand for high-purity crystalline silicon used in the production of solar PV modules exceeded supply. As a result, polysilicon prices steadily increased during the period. Between 2006 and 2007 the average long-term contract price of polysilicon increased approximately 20 per cent from between USD 50 and USD 55 per kg to between USD60 and USD65 per kilogram.[48] The strong demand continued into early 2008 when average long-term contract prices for polysilicon were between USD 60 and USD 65, with spot market silicon prices peaking at almost USD 500 per kg.[49]

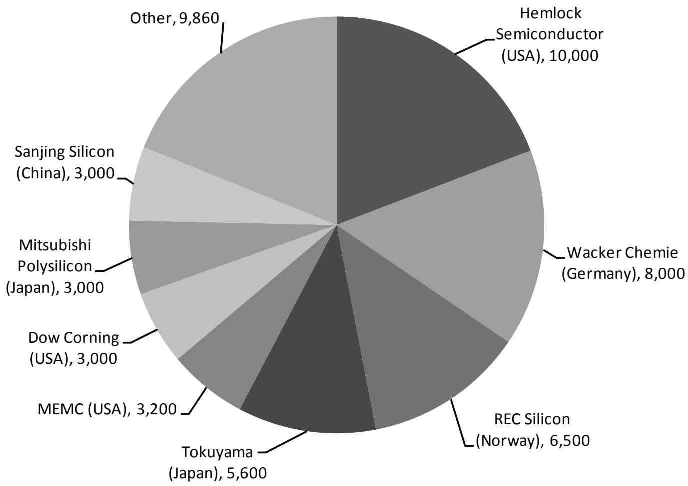
Following the global financial crisis and recession, global demand for solar power systems has dropped off considerably. While more recent average long-term contract prices are not yet available, spot market silicon prices in April 2009 fell to as low as USD 200 per kg[50] representing a 71 per cent fall in less than one year.

Polysilicon production is dominated by a relatively few, large companies. Over 80 per cent of the world's silicon supply was produced by the top 10 producers in 2007.

It is expected that many silicon producers will be detrimentally affected by the fall in prices. However, those that anticipated the price reduction, built up cash reserves and signed long-term supply contracts with downstream polysilicon users during the years of peak silicon demand, may benefit through the period as they are able to expand through merger and acquisition of smaller, less secure competitors.[51]

48 Securities and Exchange Commission, Form 20-F: Trina Solar Limited. Available at <www.sec.gov/Archives/edgar/data/1382158/000119312508141379/d20f.htm>.
49 S'Solar Industry Should Get Stronger from Polysilicon Price Drop,' Solar Feeds, 1 April 2009. Available at <www.solarfeeds.com/sc/6606-solar-industry-should-get-stronger-from-polysilicon-price-drop.html>.
50 'Solar Industry Should Get Stronger from Polysilicon Price Drop,' Solar Feeds, 1 April 2009. Available at <www.solarfeeds.com/sc/6606-solar-industry-should-get-stronger-from-polysilicon-price-drop.html>.
51 SNEC, Roadmap for a Changed Landscape, 2008. Available at <www.snec.org.cn/Read_e.asp?ID=5644>.

**Figure 3.3: Global polysilicon production capacity by company in 2007 (tonnes)**




Source: Yole Development Photovoltaic Report, 2008. Available at <yole.fr/pagesAn/products/Report_sample/Yole_PV_Technology_Equipment_and_Materials_2008_Report_Sample.pdf>.

### 3.1.2. Ingots and Wafers

Following the purification of solar PV grade silicon, ingots or crystalline silicon ribbons are produced. Ingots are produced either by growing monocrystalline rods or through the more cost-effective method of casting polysilicon ingots using molten silicon and moulds.[52]

Silicon ingots are then sliced using a variety of methods to form solar wafers. The different processes used by companies in the production of ingots and the slicing of solar wafers provide varying degrees of silicon waste and wafer quality. Relatively small improvements in wafer slicing in particular can yield considerable cost-saving benefits further down the value chain. Recent technological improvements have allowed for the slicing of silicon wafers to between 200 µm to 300 µm, or between two and three times the diameter of an average human hair.[53]

Less widely available and of slightly lower quality than monocrystalline ingots, silicon ribbons are produced using a method pioneered by Evergreen Solar. The company's ribbon production process allows for the continuous setting of molten crystalline silicon into a thin, silicon ribbon sheet, which is periodically cut into wafers. Silicon ribbon's principle benefit is its direct conversion of silicon feedstock into silicon wafers without ingot formation. By skipping this step it produces considerably less silicon waste than is lost during the ingot slicing process. In addition silicon ribbon production can be run as a continuous process, as opposed to batch methods for ingot to wafer processing.

Predictably, given the highly capital-intensive nature of the industry which serves as an effective barrier to entry, the majority of global production of silicon ingots and wafers remains dominated by a relatively few large companies. In 2006 the global market share was overwhelmingly dominated by six firms, as exhibited in Table 3.1. While this market is likely to have fragmented somewhat since then, these companies remain the largest producers of polysilicon solar ingots and wafers.

52 US Department of Energy, Energy Efficiency and Renewable Energy, April 2009. Available at <eere.energy.gov/solar/silicon.html#multi>.
53 Omron, Slicing the Ingot. Available at <www.omron-semi-pv.eu/en/wafer-based-pv/wafer-preparation/slicing-the-ingot.html>.

**Table 3.1: Global polysilicon wafer market share in 2006**

| Company | Market Share |
|---|---|
| REC | 24% |
| Solar World (Deutsche Solar) | 19% |
| PV Crystalox | 17% |
| Kyocera | 13% |
| Sumco Corporation | 6% |
| LDK Solar | 8% |
| Other | 13% |
| **TOTAL** | **100%** |

Source: Information derived from companies' websites.

## 3.1.3. Solar Cells

Solar cell production is one of the most capital intensive and technically complex processes in the crystalline silicon solar PV value chain. There are many methods used for manufacturing solar cells, each one yielding varying degrees of solar cell efficiency. These production methods are proprietary, and slight improvements offering improved power conversion efficiency benefits can give solar cell manufacturers a competitive advantage over their rivals.

According to Q-Cells, the world's largest producer of crystalline silicon solar cells, the solar cell manufacturing process generally involves the following steps:[54]

1. Quality inspection of solar wafers to establish, amongst other measures, their electrical properties and surface condition.
2. Cleaning and texturing to strip chemically the surface of the wafer of any impurities and to create a surface texture which improves sunlight utilisation. The texturing process in particular is considered a key input to a completed cell's power conversion efficiency.[55]
3. Using a "diffusion furnace" operating at between 800 and 900 degrees Celsius, anegatively conducting phosphorous surface layer is applied into the positively conducting silicon wafer. This creates the basic solar cell, with a negatively conducting front surface layer and a positively conducting back surface layer.
4. The edges of the cell are insulated, and then phosphorous silicate glass, produced during the diffusion process, is chemically removed from the surface of the cell.
5. The cell is coated with silicon nitrate to reduce its reflective quality.
6. A pattern of silver paste is applied by screen printing to the front of the cell and then burned into the cell's silicon substrate. This creates the electrical contacts through which the current will flow. Silver/aluminium contact strips and an additional layer of aluminium are applied to the back surface layer of the cell in the same manner.
7. Finished solar cells are then tested to establish their performance and quality categories.

This reduced and simplified description of the cell manufacturing process using a silicon wafer gives some idea of the complexity of the production method as well as the number of sequential processes involved. At any point in this process, slight improvements can contribute to substantial increases in the finished cell's power conversion efficiency.

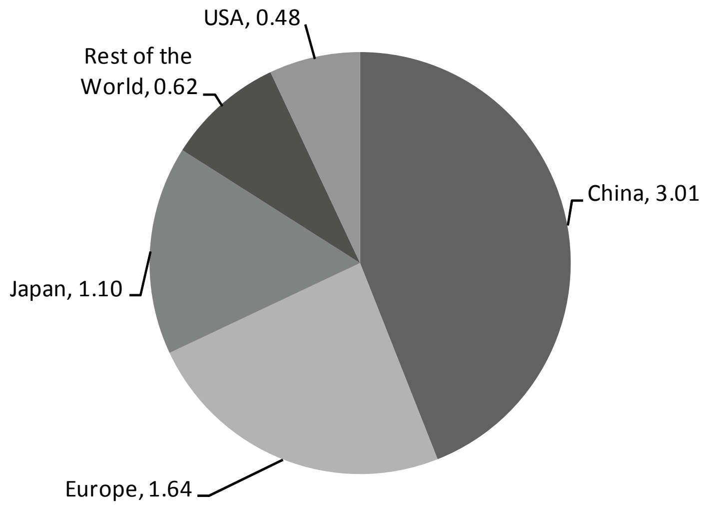
54 Q Cells, Investor Relations. Available at <www.q-cells.com/en/investor_relations/index.html>.
55 E. Ryabova, 'A Review of Solar Wafer Cleaning and Texturing Methods,' Renewable Energy World, 30 April 2009. Available at <www.renewableenergyworld.com/rea/news/article/2009/04/a-review-of-solar-wafer-cleaning-and-texturing-methods>.

### *3.1.3.1. Global Solar Cell Output*

The total global output of solar cells in 2008 was 6.85 GW, representing an increase of almost 100 per cent over the 3.44 GW produced in 2007. Of this, 44 per cent was produced in China, where solar cell production has grown dramatically since 2006.

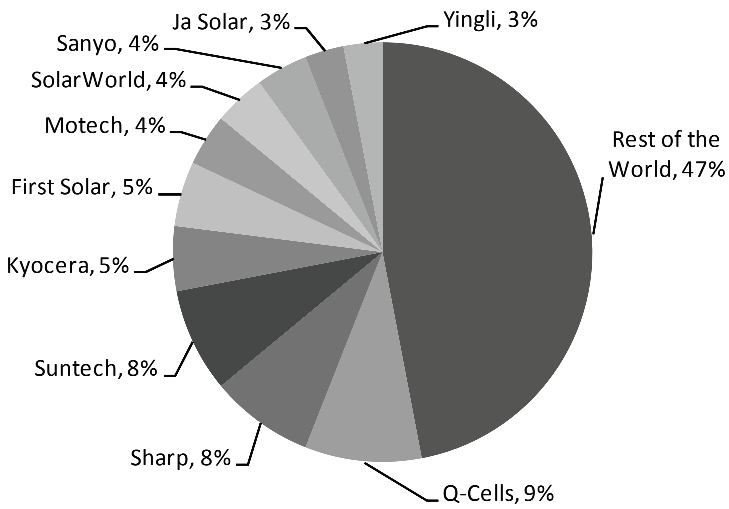
As illustrated in Figure 3.4, solar cell production remains concentrated in four countries/ regions.

**Figure 3.4: Solar cell production by country/region in 2008 (GW)**




Derived from: Solar Buzz, available at <www.solarbuzz.com> and Intech, China's White Hot Solar Cell Production, 7 April 2009. Available at <www.isa.org/InTechTemplate.cfm?Section=Automation_Update&template=/ContentManagement/ContentDisplay.cfm&ContentID=75501>.

**Figure 3.5: Top 10 solar PV cell manufacturers in 2007**




European Photovoltaic Industry Association and Greenpeace, Solar Generation V, September 2008. Available at <www.epia.org/fileadmin/EPIA_docs/documents/EPIA_SG_V_ENGLISH_FULL_Sept2008.pdf>.

From 2007 to 2008, in response to the high demand for solar cells, the total number of firms producing solar cells increased, which resulted in a slight fragmentation of the market.[56] The top 10 solar PV cell producers in 2007 are provided in Figure 3.5.

### *3.1.3.2. Thin-Film Technology*

Thin-film technology was developed largely in response to high crystalline silicon prices. Despite considerable investment in the development and manufacturing capacity of thin-film technology, a mere 10 per cent of solar modules are currently made using thin-film cells.[57]

The thin-film value chain differs in its use of semiconductive materials other than crystalline silicon which are applied to a substrate material, such as plastic.[58] The cost of machinery and technical expertise required for thin-film production remains relatively high, however the material input costs are substantially lower than those for crystalline silicon production.

Thin-film technology differs from crystalline silicon-based technology in that it uses a relatively small amount of semiconductor material deposited on a less expensive and widely available substrate such as plastic. The most widely used and commercially viable semiconducting materials currently being developed within the thin-film group are non-silicon types such as copper indium gallium selinide (CIGS), copper indium selinide (CIS), cadmium telluride (CdTe), as well as other non-crystalline “amorphous” silicon.

For large-scale, ground-based solar PV systems, the cost contribution of amorphous silicon solar modules to total system cost is, according to Schott Solar, 51 per cent. This is approximately 22 per cent less than the 73 per cent contribution to total system cost from crystalline silicon solar PV modules.[59] The benefits of thin film are not only the lower cost of input materials, but also:

- The potential for the automation of its manufacturing processes
- The improved size and shape flexibility offered by thin-film cell production
- The possibility of integrating thin film into building components at some point in the future.

Many thin-film technologies have substituted the silver or aluminium mesh, which acts as the electrical contact point on the surface of crystalline silicon cells, with a transparent conducting material such as tin oxide, indium oxide or zinc oxide, maximising the solar absorbing surface area of the thin-film cell.

Advanced thin-film third generation PV cells are in the research and development pipeline. Advanced thin film is manufactured using production methods similar to those employed in existing thin-film manufacture, however, with alternative semiconductive and non-semiconductive materials. Advanced thin-film technologies remain experimental and extremely costly and are therefore not credible competitors to crystalline silicon wafer or conventional thin-film technologies at this stage.

Currently the largest solar module producers dominate the production of both solar cell and thin-film solar modules, whilst the development of advanced thin-film technology remains

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56 Q Cells, Investors Presentation, 2009. Available at <www.q-cells.com/medien/ir/praesentationen/2009/presentation_q1_2009_englisch.pdf>.
57 ‘Solar Cell Technologies,’ Solar Buzz, April 2009. Available at < solarbuzz.com/Technologies.htm>.
58 PhotoVoltaic Technology Platform, A Strategic Research Agenda for Photovoltaic Solar Energy Technology, 2007. Available at <cordis.europa.eu/technology-platforms/pdf/photovoltaics.pdf>.
59 I.A. Schwirtlich, P. Lechner, H. Nagel, Schott Solar: EPIA Industry Forum - 23rd European Photovoltaic Solar Energy Conference, Valencia September 3rd 2008. Available at <epia.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/EPIA_docs/documents/23EUPVSEC/Presentations/IF_3_1_Schwirtlich.pdf&t=1246361660&hash=b364c374a0bd86a567e3a7c188e03d29>.

concentrated in various commercial research and development departments, scientific research facilities, and government agencies such as NASA.

### 3.1.4. Solar Modules

The term "solar module" refers to a group of interconnected solar cells enclosed in an environmentally sealed larger unit. Solar modules are made up of a transparent material on the front of the module (solar cells), a back cover material and generally a frame or casing unit. Recent production and material input improvements have considerably enhanced the resilience and cost effectiveness of solar PV modules.[60]

Solar modules are generally designed either as concentrator photovoltaic (CPV) systems or as flat-panel PV systems.[61] Concentrator PV modules use metal sheets or lenses, made from plastic or other similar materials, to focus light onto a small point where a solar cell is located. The primary benefit of this design is the improved utilisation per square inch of each solar cell. Concentrator PV modules therefore generally require fewer solar cells per unit than flat-plate modules. The primary drawback to concentrator PV modules is their need for direct sunlight in order to operate effectively.[62] The converse is true for flat-panel modules which require a relatively large surface area of solar cells but are effective in both direct and indirect sunlight and therefore more practical and versatile. Further benefits of flat-panel modules are that they are less complex to design and more compatible with single- or dual-axis sun-tracking balance of system (BOS) technology.

For both concentrator PV and flat-panel modules, the ultimate efficiency of a solar module is heavily reliant on the quality of the solar cells, the quality of all other materials used in the module and its overall design. Efficiencies and performance related to internal electrical connections and module mountings play a particularly important role in determining the final quality of a solar module.

### 3.1.5. Project Development, System Integration and Balance of System Production

The final stage of the solar PV value chain involves the project developers, system integrators and manufacturers of the so-called balance-of-system (BOS) components. BOS has traditionally referred to the additional material inputs required to make a solar module or array operational. This includes the inverter and all other physical inputs such as the structural foundations, frames, mounts, solar trackers and electrical wiring. More recently the term has increasingly been used to refer to all cost items from installation to ongoing operation and maintenance. Whilst there are many functions and material inputs required at this development and system integration stage, this report will group all service providers and manufacturers active in this segment of the value chain as a collective whole.

One of the crucial components in any PV system is the direct current (DC) to alternating current (AC) inverter. There are two main types of inverter, those that operate as part of a grid-independent system and those that are connected to the grid and synchronise solar PV output with the grid. One negative aspect of all inverter design is its need to consume power even when a PV system is not generating any electricity.

The type and scale of construction required during installation varies considerably dependent on such factors as whether the system is roof or ground-mounted, the array size, the weather

60 SEPA, PV Facts. Available at <www.solarelectricpower.org/index.php?page=basics&subpage=pv&display=facts>.
61 EERE, Solar Concentrator. Available at <www1.eere.energy.gov/solar/concentrator_systems.html>.
62 SEPA, PV Facts. Available at <www.solarelectricpower.org/index.php?page=basics&subpage=pv&display=facts>.

conditions at the installation site, the required tilt of the array and whether any additional tracking equipment is used. Fixed south-facing mountings are generally the simplest and least expensive to install as there are no moving parts to consider; the primary consideration for these is the tilt and direction of the array.

## 3.2. Solar PV Value-Added Production Costs

The value-added production cost for a finished crystalline silicon solar module is dominated by the cost of solar cell and solar module production. This is due to the complex, labour intensive multi-stage production methods involved at these stages of the value chain. Conversely, for silicon feedstock and wafer production, the initial capital investment costs are high. However, the production processes employed are comparatively simple, involving fewer material inputs and process stages.

The specific value-added production costs for crystalline solar PV systems vary between companies (see Figures 3.6 and 3.7). According to Schott Solar AG, a large vertically integrated solar PV module producer, solar module and cell value-added production costs account for almost two thirds of the total value added in the module production process. According to a specialist solar PV project developer in the UK, the value-added production costs for Chinese solar modules is slightly different, with the cost of solar wafers considerably lower than those achieved by Schott Solar AG in the production of their solar modules.

**Figure 3.6: Value-added production costs for Chinese crystalline solar PV modules**

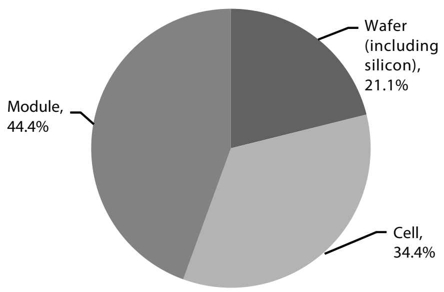
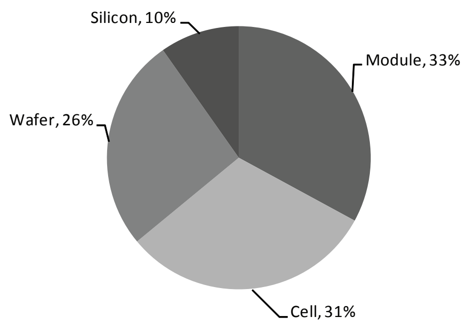



**Figure 3.7: Value-added production costs for European crystalline solar PV modules**



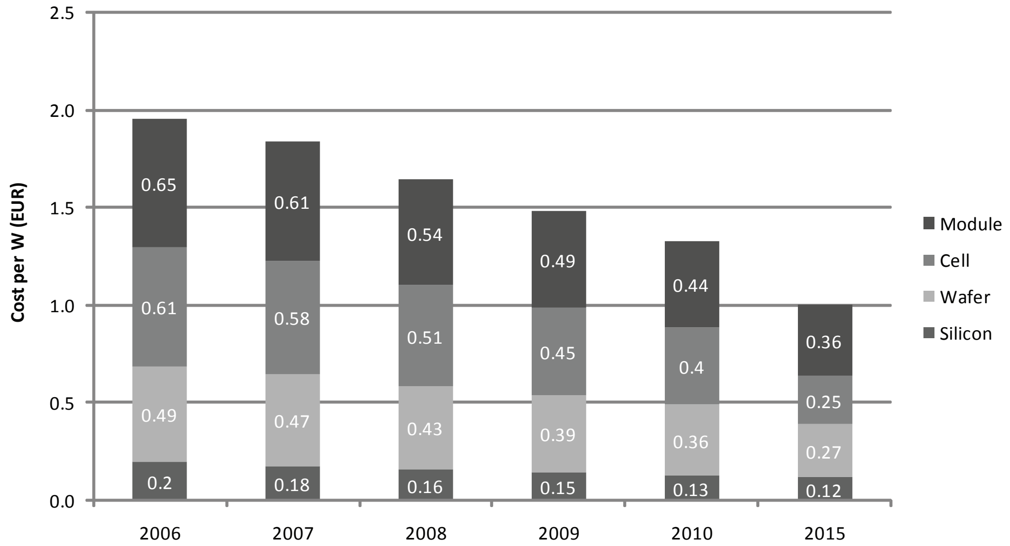

Source for figure 3.6: I.A. Schwirtlich, P. Lechner, H. Nagel, Schott Solar: EPIA Industry Forum - 23rd European Photovoltaik Solar Energy Conference, Valencia 3 September 2008. Available at <www.epia.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/EPIA_docs/documents/23EUPVSEC/Presentations/IF_3_1_Schwirtlich.pdf&t=1246361660&hash=b364c374a0bd86a567e3a7c188e03d29>.
Source for figure 3.7: Interview with a specialist UK solar PV project developer, June 2009.

The cost of solar system components varies between countries because of different input costs such as labour. On the whole, European solar power system component prices are higher than their Chinese equivalents, in part due to their higher quality and more established brands,[63] but also because of the lower cost of labour in China. Figure 3.9 illustrates the approximate value-added production costs per W for a roof-mounted, commercial solar PV system installation, and the increased gross profit margin available to installers using Chinese system components. For smaller solar PV systems and BIPV systems, system cost per W is higher. It is anticipated that the cost of solar system integration and BOS component costs will fall as

63 Form 20-F, Trina Solar. Available at <ccbn.10kwizard.com/cgi/convert/pdf/TrinaSolarLtd20F.pdf?ipage=6292978&num=-2&pdf=1&xml=1&cik=1382158&odef=8&rid=12&quest=1&xbrl=0&dn=2&dn=3>.

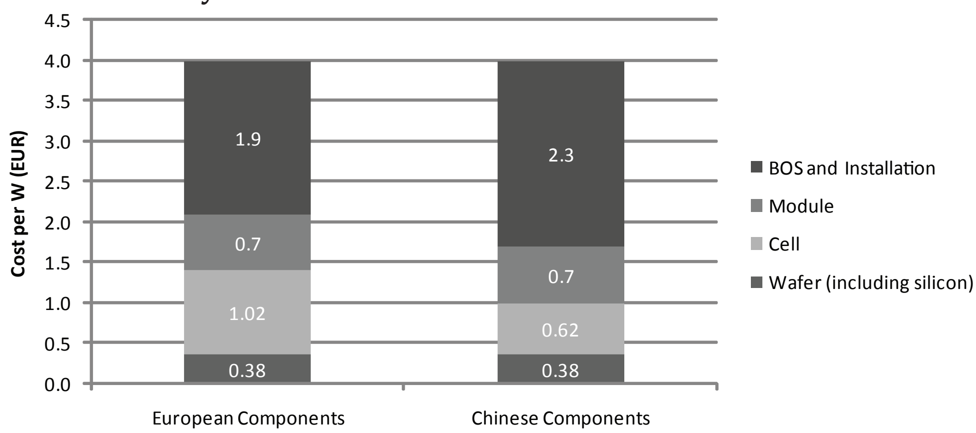
the pool of expertise involved in installation and project management of solar power systems increases, particularly when grid parity approaches and demand for stand-alone solar PV systems grows.

**Figure 3.8: Value-added production costs for a crystalline silicon solar PV module producer**




Note: Total module costs per W do not necessarily represent actual solar module market prices available to project developers. As a vertically integrated company, the value-added production costs achieved by Schott are lower than for other non-integrated firms.
Source: I.A. Schwirtlich, P. Lechner, H. Nagel, Schott Solar: EPIA Industry Forum - 23rd European Photovoltaik Solar Energy Conference, Valencia September 3rd 2008. Available at <www.epia.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/EPIA_docs/documents/23EUPVSEC/Presentations/IF_3_1_Schwirtlich.pdf&t=1246361660&hash=b364c374a0bd86a567e3a7c188e03d29>.

**Figure 3.9: Approximate value-added production costs for crystalline silicon solar PV systems**




Note: Value-added production costs available to a non-integrated solar PV project development specialist are higher than those achieved by a vertically integrated firm.
Source: Interview with a specialist UK solar PV project developer, June 2009.

## 3.3. Industry Goals

The European solar PV sector is experiencing an unprecedented level of competition. During a period of rapid market growth from 2004 to 2008, both the number of new entrants in the sector and the size of incumbents grew considerably. As the financial crisis and recession continue to weaken demand for solar power systems, both established incumbents and new entrants are competing to retain or grow their market shares by offering increasingly efficient solar power systems at lower prices. Any increase in the efficiency of a solar power system or reduction in its total cost can substantially lower the levelised generation cost of solar power.

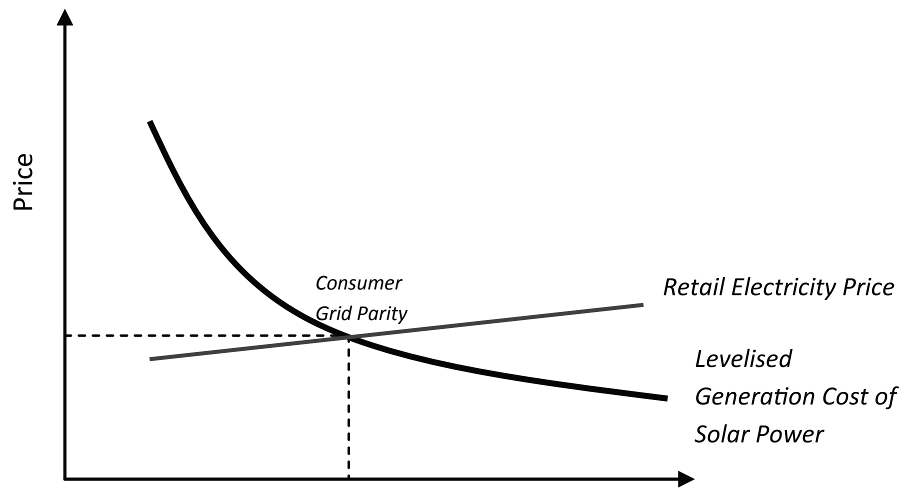
Heightened competition in the solar PV sector and the reduction of the levelised generation cost of solar power leads to the two main industry goals:

- Consumer grid parity
- Commercial solar power price competitiveness.

### 3.3.1. Consumer Grid Parity

Consumer grid parity is the term used to describe the situation where the levelised generation cost of electricity from a solar PV installation over its useful lifespan is equal to the cost of an equivalent amount of electricity sourced by a consumer from the grid over the same period.[64] More simply, consumer grid parity is the point in time when the cost of installing and generating electricity from a solar PV system is equal to the price paid by consumers for retail electricity (see Figure 3.10).[65]

**Figure 3.10: Relationship between retail electricity price and levelised generation cost of solar power**




Many factors impact the solar PV sector's progress towards consumer grid parity, most important of which are:

64 Solar Century, Solar Electricity as Cheap as Conventional, May 2009. Available at <www.solarcentury.co.uk/News/Solarcentury-News/Solar-electricity-as-cheap-as-conventional-electricity-by-2013>.
65 IEA PVPS, Trends in Photovoltaic Applications, 2008. Available at <www.iea-pvps.org/products/download/rep1_17.pdf>.

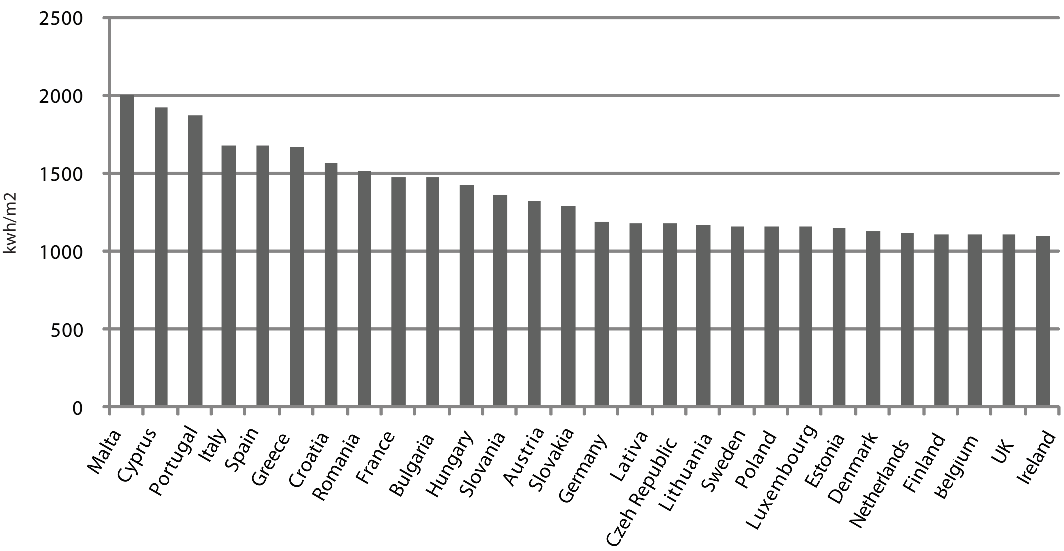
- The climate in which the solar power is being generated, including a location's solar irradiation levels, wind speeds and temperature
- The price of electricity paid by a consumer in a region
- The power conversion efficiency of solar cells and modules, amongst other loss and efficiency factors
- The total cost of ownership of solar PV installations.

On an industry level, the two factors that can directly influence the solar PV sector's progress towards grid parity are the power conversion efficiency of solar modules, and the total cost of their acquisition, installation and operation. These two will be analysed in greater detail in Sections 3.4 and 3.5.

### *3.3.1.1. Solar Irradiation*

Generating electricity from the sunlight is dependent on solar irradiation reaching the earth. As shown in Figure 3.11. The countries in Europe which have the greatest solar irradiation levels, and are therefore best suited to solar power generation, are the southern member states.

**Figure 3.11: Comparison of yearly irradiation incident on optimally inclined photovoltaic systems in a sample of European countries**




Note: Solar irradiation levels are calculated as the median between the highest and lowest irradiation levels received in 90 per cent of the built-up areas of each country.
Source: Šúri M., Huld T.A., Dunlop E.D. Ossenbrink H.A., 2007. Potential of solar electricity generation in the European Union member states and candidate countries. Solar Energy, 81, 1295–1305, 2007. Available at <re.jrc.ec.europa.eu/pvgis>.

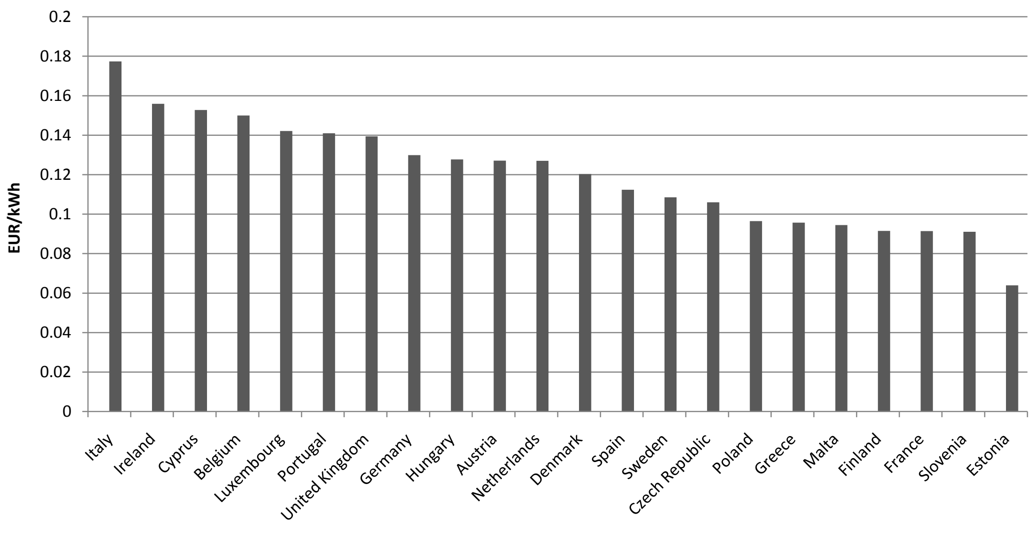
There is a close relationship between solar irradiation levels and the output of solar power systems. The same solar power system that can generate, for example, 900 kWh annually in Germany could generate approximately 1,400 kWh annually in sunnier European countries such as Spain, Portugal, France, Italy and Greece. With climates that allow PV systems to produce approximately 50 per cent more electricity compared to Germany, each of these southern European countries should have a considerable advantage in the race to reach grid parity. A country's solar irradiation level is, however, only one factor among many that contribute to the size of its solar power sector. Ironically, Germany has emerged as the world's leader in installed solar PV capacity, despite having a less-than-ideal climate, due to government incentives. By contrast, the UK, which has only slightly lower levels of solar irradiation than Germany, has a relatively small solar power sector, largely due to its lack of attractive government incentives.[66]

### *3.3.1.2. Electricity Prices*

Another important factor in determining the point at which grid parity is reached is the price that consumers pay for electricity. One benefit of stand-alone solar power installations is that the electricity produced does not go through the grid, and hence there are no charges from using transmission or distribution systems. The electricity price paid by consumers in different countries will therefore have an effect on each country's progress towards achieving grid parity, as in countries with higher retail electricity prices the relative cost of solar power generated using a stand-alone solar PV system can be lower than in countries with low retail electricity prices.

Fluctuations in currency exchange rates make a comparison between retail electricity prices in different countries difficult. A comparative figure based on the Eurostat database of electricity prices for consumers in a sample of European countries is provided in Figure 3.12.

**Figure 3.12: Consumer electricity prices in a sample of European countries in 2008 (EUR/kWh, excluding taxes)**




Note: Electricity price in Italy 2008 price not available as yet; indicative price given using assumed annual price increase of 7 per cent.
Source: Eurostat, Electricity: Domestic Consumers, Half-Yearly Electricity Prices, May 2009. Available at <epp.eurostat.ec.europa.eu>.

Similarly, changes in retail electricity prices over time in any country have an effect on solar power's progress towards grid parity. In countries where the price of electricity is expected to increase in real terms, grid parity is expected to be reached sooner. It is expected that electricity

66 Ashley Seager, 'Sunnier Times Ahead for Solar Energy,' Guardian, 15 June 2009. Available at <www.guardian.co.uk/business/2009/jun/15/solar-photovoltaic-power-motion>Ashley Seager, 'Sunnier Times Ahead for Solar Energy,' Guardian, 15 June 2009. Available at <www.guardian.co.uk/business/2009/jun/15/solar-photovoltaic-power-motion>.

prices will rise as oil prices rise due to increasing demand, mainly from the transportation sectors in India, China and other developing countries. Table 3.2 illustrates the changes in the consumer electricity price in a sample of European countries between 2004 and 2008.

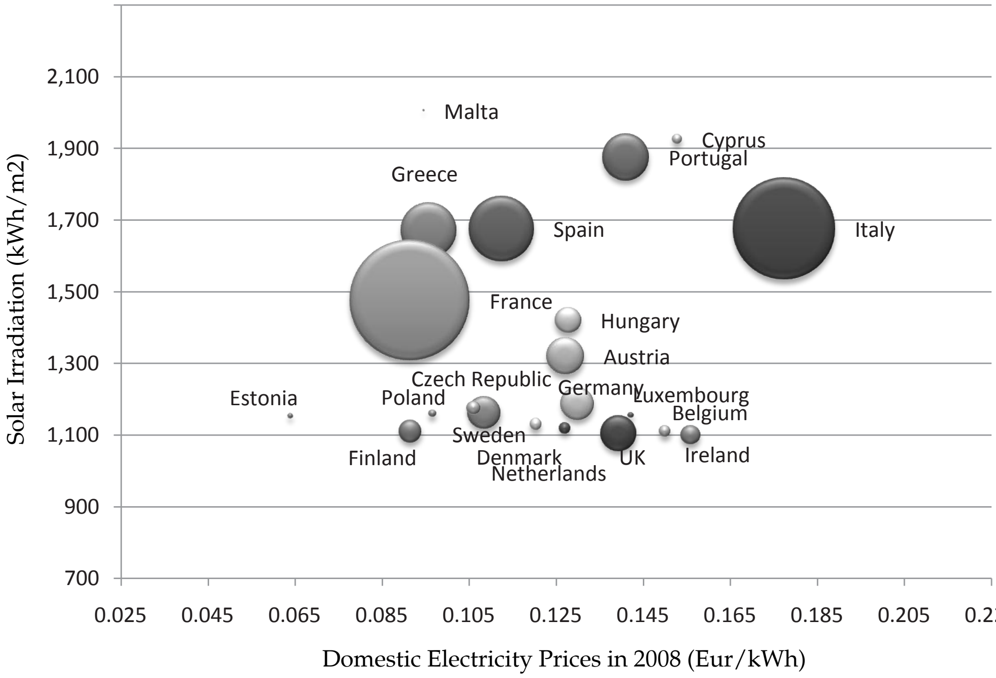
The relationship between solar irradiation and the domestic cost of electricity in 2008 is represented in Figure 3.13. For certain European countries, such as Italy and France, the solar irradiation levels vary considerably between different regions. This range of solar irradiation levels is reflected in the size of the bubbles in Figure 3.13 which illustrates how different regions within the same country are likely to reach consumer grid parity before others.

**Table 3.2: Domestic electricity prices (excluding taxes) in the EU from 2004 to 2008 (EUR/kWh)**

| Country | 2004 | | 2005 | | 2006 | | 2008 | | 2008 | (2004-2008) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Price | Increase | Price | Increase | Price | Increase | Price | Increase | Price | CAGR[a] |
| Italy[b] | 0.1434 | 0% | 0.144 | 8% | 0.1548 | 7% | 0.1658 | 7% | 0.177406 | 5.46% |
| Ireland | 0.1055 | 13% | 0.1197 | 7% | 0.1285 | 14% | 0.1465 | 6% | 0.1559 | 10.26% |
| Cyprus | 0.0928 | -1% | 0.0915 | 34% | 0.1225 | -4% | 0.1177 | 30% | 0.1528 | 13.28% |
| Belgium | 0.1145 | -3% | 0.1116 | 1% | 0.1123 | 9% | 0.1229 | 22% | 0.15 | 6.98% |
| Luxembourg | 0.1215 | 6% | 0.1288 | 8% | 0.139 | 9% | 0.1509 | -6% | 0.1421 | 3.99% |
| Portugal | 0.1283 | 2% | 0.1313 | 2% | 0.134 | 6% | 0.142 | -1% | 0.141 | 2.39% |
| United Kingdom | 0.0837 | 0% | 0.0836 | 16% | 0.0971 | 29% | 0.1254 | 11% | 0.1394 | 13.60% |
| Germany | 0.1259 | 6% | 0.1334 | 3% | 0.1374 | 4% | 0.1433 | -9% | 0.1299 | 0.78% |
| Hungary | 0.0794 | 7% | 0.0851 | 5% | 0.0896 | 14% | 0.1019 | 25% | 0.1277 | 12.61% |
| Austria | 0.0981 | -2% | 0.0964 | -7% | 0.0894 | 17% | 0.105 | 21% | 0.1271 | 6.69% |
| Netherlands | 0.1031 | 7% | 0.1102 | 10% | 0.1207 | 16% | 0.14 | -9% | 0.127 | 5.35% |
| Denmark | 0.0915 | 1% | 0.0927 | 8% | 0.0997 | 17% | 0.117 | 3% | 0.1203 | 7.08% |
| Spain | 0.0885 | 2% | 0.09 | 4% | 0.094 | 7% | 0.1004 | 12% | 0.1124 | 6.16% |
| Sweden | 0.0898 | -6% | 0.0846 | 4% | 0.0876 | 24% | 0.1088 | 0% | 0.1085 | 4.84% |
| Czech Republic | 0.066 | 10% | 0.0729 | 14% | 0.0829 | 8% | 0.0898 | 18% | 0.106 | 12.57% |
| Poland | 0.0699 | 18% | 0.0823 | 12% | 0.0923 | 2% | 0.0945 | 2% | 0.0965 | 8.40% |
| Greece | 0.0621 | 3% | 0.0637 | 1% | 0.0643 | 3% | 0.0661 | 45% | 0.0957 | 11.42% |
| Malta | 0.0636 | 14% | 0.0727 | 24% | 0.0904 | 4% | 0.094 | 1% | 0.0945 | 10.41% |
| Finland | 0.081 | -2% | 0.0792 | 2% | 0.0809 | 8% | 0.0877 | 4% | 0.0915 | 3.09% |
| France | 0.0905 | 0% | 0.0905 | 0% | 0.0905 | 2% | 0.0921 | -1% | 0.0914 | 0.25% |
| Slovenia | 0.0841 | 2% | 0.0861 | 2% | 0.0874 | 1% | 0.0887 | 3% | 0.0911 | 2.02% |
| Estonia | 0.055 | 5% | 0.0576 | 8% | 0.062 | 2% | 0.0635 | 1% | 0.0639 | 3.82% |

Notes: N/A: not available;
CAGR = Compounded Annual Growth Rate ;
Electricity price in Italy 2008 price not available as yet; indicative price given using assumed annual price increase of 7 per cent.
Source: Eurostat, Electricity: Domestic Consumers, Half-Yearly Electricity Prices, May 2009. Available at <epp. eurostat.ec.europa.eu>.

**Figure 3.13: Solar irradiation and domestic cost of electricity in Europe in 2008**




Notes: Bubble sizes represent ranges in solar irradiation over 90 per cent of the built-up areas of each country, as detailed in Figure 3.11; Electricity prices for each country do not include taxes and hence would be considerably higher in most instances. Levelised generation cost frontier is provided as an in Figure 3.14.
Sources: Eurostat and Šúri M., Huld T.A., Dunlop E.D. Ossenbrink H.A., 2007. Potential of solar electricity generation in the European Union member states and candidate countries. Solar Energy, 81, 1295–1305, 2007. Available at <re.jrc.ec.europa.eu/pvgis>.

## 3.3.2. Progress towards Consumer Grid Parity

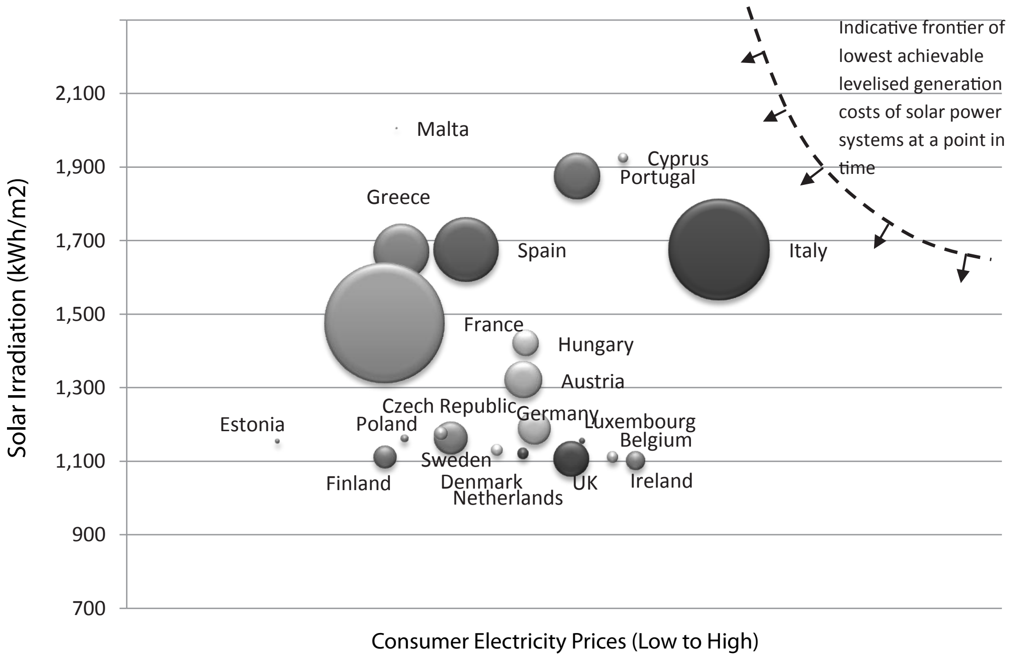
Measures of the solar PV sector's progress towards grid parity include the levelised generation cost of solar power over the useful lifespan of a solar PV system and both the solar irradiation and retail price of electricity in each country. The solar industry's position relative to attaining consumer grid parity can therefore be shown as a frontier representing the lowest possible levelised cost per kWh of solar power under different solar irradiation conditions using the most efficient and lowest cost solar power systems available at a point in time. The frontier line will represent the market leader in terms of system cost and efficiency with all other systems located behind the frontier line, offering a higher electricity cost at each level of solar irradiation. Figure 3.14 illustrates that some countries with high electricity prices and high levels of solar irradiation are likely to reach grid parity sooner than others.

The solar power levelised generation cost frontier is dependent on a number of variables, particularly around assumptions regarding the rate of total cost reductions of solar PV system components and improvements in the power conversion factor that includes system loss factor and effective output decrease. As of yet, no company or organisation can claim to have developed a truly robust model capable of predicting when grid parity will be reached. However, the principle remains that as a solar power system's *efficiency in converting sunlight to electricity* and the *total cost of ownership of solar power systems falls*, the levelised generation cost of solar power will fall, shifting the solar power generation frontier to the right. Assuming no dramatic fall in consumer electricity prices, it is likely that Italy and Portugal will be the first major European markets to reach grid parity.

Q-Cells, the world's largest producer of solar cells, anticipates that the reduction of PV production costs and increase in power conversion efficiency will continue at a rate at which grid parity will be brought to both residential and commercial consumers in Italy by 2012.

Italy has relatively high retail electricity prices and high levels of solar irradiation and, according to Q-Cells' company analysis, will be the first major European country to reach this milestone. Using different rates of power conversion efficiency improvement for solar PV technology generally, termed the "industry learning curve", as well as assumptions regarding increases in the average price of electricity in different European countries, Q-Cells has estimated that by 2020 a majority of European countries will have reached grid parity (see Figure 3.15).[67]

**Figure 3.14: Levelised generation cost of solar power relative to solar irradiation and consumer electricity prices in a sample of European countries**



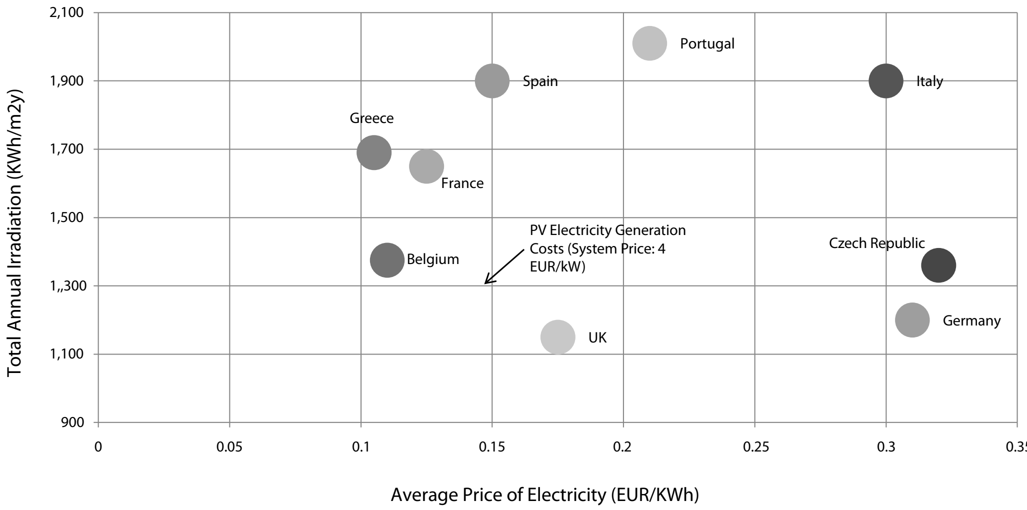

Note: Bubble sizes represent ranges in solar irradiation over 90 per cent of the built-up areas of each country, as detailed in Figure 3.14. Sources: See Figure 3.11 and Table 3.2.

## 3.3.3. Commercial Solar Power Price Competitiveness

In the same way that the retail price of electricity provides a benchmark target for the reduction of levelised generation cost of stand-alone solar power systems, the levelised generation cost of fossil-fuel power plants connected to the transmission and distribution systems, or simply wholesale electricity prices, provides the target generation cost for large-scale commercial solar power arrays. Table 3.3 shows the relative generation costs of a range of renewable and non-renewable power technologies.

67 Q Cells Presentation of Financial Year 2008, 19 March 2009. Available at <q-cells.com/medien/ir/praesentationen/2009/financial_year_2008.pdf>.

**Figure 3.15: Progress towards consumer grid parity in Europe by 2020**




Note: Variations in solar irradiation figures from those in Figure 3.14 due to use of alternative references. Assumptions: 20 per cent learning curve, system price 4 EUR/W, 6.4 per cent return on investment, operations and maintenance at 1.5 per cent of capital expenditure, system lifespan of 20 years, performance ratio of 80 per cent, weighted average cost of capital 6.4 per cent.
Source: Derived from Q Cells Presentation of Financial Year 2008, 19 March 2009. Available at <q-cells.com/medien/ir/praesentationen/2009/financial_year_2008.pdf>.

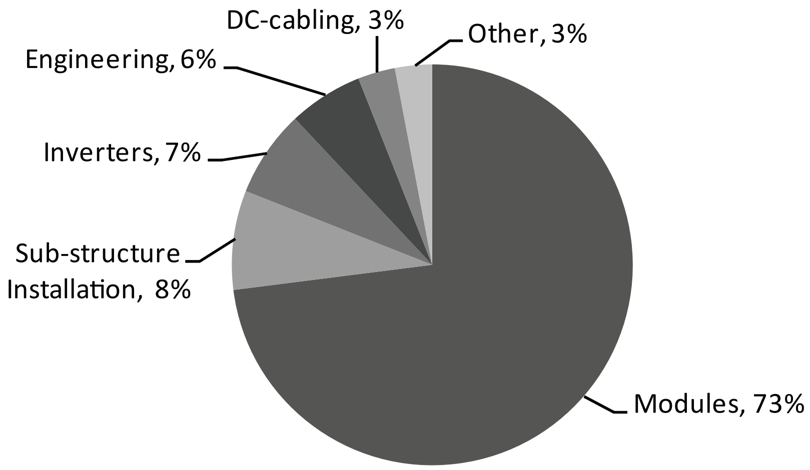
**Table 3.3: Comparison of the levelised electricity generation cost of selected technologies (EUR/MWh)**

| Technology | | | Actual 2005 cost | Projected cost for 2030 |
|---|---|---|---|---|
| 1 | Natural gas | Open cycle gas turbine | 45–70 | 55–85 |
| | | Combined cycle gas turbine | 65–45 | 40–55 |
| 2 | Oil: Diesel engine | | 70–80 | 80–95 |
| 3 | Coal | Pulverised fuel | 30–40 | 45–60 |
| | | Integrated gasification combined cycle | 40–50 | 55–70 |
| 4 | Light-water nuclear fission | | 40–45 | 40–45 |
| 5 | Biomass generation plant | | 25–85 | 25–75 |
| 6 | Wind | Onshore | 35–175 | 28–170 |
| | | Offshore | 50–170 | 50–150 |
| 7 | Hydro | Large | 25–95 | 25–90 |
| | | Small | 45–90 | 40–80 |
| 8 | Solar PV | | 140–430 | 55–260 |

Source: IEA, 2005. Costs do not include grid related investment costs or charges. Figures were converted from USD to EUR by the European Commission.

Companies such as First Solar have made progress in lowering the generation cost of large-scale commercial solar power installations, claiming to have reduced the production cost of solar modules to below 1 USD/W.[68] However, many in the industry believe that without a technological breakthrough, solar power cannot compete with fossil-fuel power.[69] This is in part due to the relatively high contribution of solar module cost to total cost of a crystalline silicon solar PV system. The contribution of solar module cost to total cost varies greatly, however, it remains the highest single cost for all large solar PV systems (see Figure 3.16).

**Figure 3.16: Cost breakdown for crystalline silicon ground-based PV systems**




Source: I.A. Schwirtlich, P. Lechner, H. Nagel, Schott Solar: EPIA Industry Forum - 23rd European Photovoltaik Solar Energy Conference, Valencia September 3rd 2008. Available at <www.epia.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/EPIA_docs/documents/23EUPVSEC/Presentations/IF_3_1_Schwirtlich.pdf&t=1246361660&hash=b364c374a0bd86a567e3a7c188e03d29>.

### *3.3.3.1. Major Project Developers*

Until recently, the dominant solar PV developers were in Germany, a country which offered developers opportunities with little risk for renewable power development. However, as attractive sites in Germany have become scarcer and other European countries have begun to compete on FIT rates, solar PV developers have moved aggressively into new markets. More than a dozen German firms have developed utility-scale (>1 MW) projects in Spain and there has been a surge of German investment in Italy and Greece.

After observing German firms succeed in their countries, and faced with newer and less generous domestic FIT rates, several Spanish solar PV developers, such as Solaria, are now seeking opportunities beyond their borders. As with the German multinationals, Italy and Greece are the most common expansion destinations for solar PV firms. Interestingly, the multinational firm that has been most successful in the Portuguese market is not German or Spanish, but rather the US firm SunPower, which recently completed an 11 MW solar PV plant in that country.

The solar PV sector is one in which economies of scale matter, as costs related to lengthy planning permission alone could force small developers out of business. Table 3.4 provides a profile of six major project developers that are active in several European markets.

68 First Solar, Investor Information. Available at <investor.firstsolar.com/phoenix.zhtml?c=201491&p=irol-newsArticle&ID=1259614&highlight=>.

69 Ed Crooks, 'Sun Sets on BP's Solar Hopes,' Financial Times, 13 May 2009. Available at <www.ft.com/cms/s/0/d7b2a18e-3ff3-11de-9ced-00144feabdc0.html>.

**Table 3.4: Profile of a sample of major international solar project developers**

| Firm (country) | Turnover (2008) | Country Coverage | Project Example |
|---|---|---|---|
| Conergy (Germany) | EUR 1,006 million | Germany, Italy, Greece, Spain, Singapore, USA | 4 MW (Hemau, Germany) |
| Solarworld (Germany) | EUR 900 million | Germany, Spain, South Africa, South Korea, Singapore, USA, France, Greece, Italy | 15 MW (Jeollabukdo, South Korea) |
| SOLON (Germany) | EUR 875 million | Germany, Austria, Switzerland, Italy, USA | 12 MW (Arnstein, Germany) |
| SunPower (USA) | EUR 750 million | USA, Canada, Switzerland, Germany, Spain, Italy,Portugal, Australia, South Korea, | 11 MW (Serpa, Portugal) |
| Phoenix Solar (Germany) | EUR 402 million | Germany, Spain, Italy, Greece, Singapore, Australia | 6.9 MW (Murcia, Spain) |
| Solaria (Spain) | EUR 119 million | Spain, Greece, Italy | 3 MW (Toledo, Spain) |

## 3.4. Power Conversion Efficiency

As mentioned in Section 3.3.1, the two most important goals for firms in the solar PV sector are to reduce the total cost of ownership of solar PV systems, and simultaneously to improve the power conversion efficiency.

Conversion efficiency is the percentage of power that is converted from absorbed light energy into electrical energy through a solar power system. It is calculated as the power output of a cell or module at the maximum power point (MPP)[70] of a solar PV circuit, divided by the product of the solar irradiance (W/m$^2$) and the surface area of the solar cell or module (m$^2$). The conversion efficiency rating assumes “Standard Test Conditions”, with a temperature of 25 degrees Celcius, irradiation of 1,000 Wh/m$^2$ and other conditions simulating direct sunlight. It is most often used to calculate the efficiency of solar cells and modules.

The output of a solar power system is therefore calculated as the product of a solar cell or module’s efficiency, its surface area, the solar irradiation and system losses.

### 3.4.1. Research & Development Investment

Total investment in research and development (R&D) in the solar PV sector has increased dramatically as firms attempt to improve the competitiveness of their products by increasing the power conversion efficiencies that can be achieved. The relationship between government incentives and R&D funding is shown in Figure 3.17.

For new entrant solar PV firms, R&D in innovative technologies is critical in overcoming the high barriers to entry, particularly upstream in the solar PV value chain. Incumbent firms have had to invest heavily in R&D to try and stay ahead of the industry learning curve and minimise their susceptibility to potentially disruptive technologies or improved products offered by competitors. Table 3.5 illustrates the increase in R&D investment by a sample of large, integrated solar PV firms.

70 The MPP is the load resistance where the voltage and current values through a solar cell or module result in maximum power output, see <daviddarling.info/encyclopedia/M/AE_maximum_power_point.html>.

**Figure 3.17: Relationship between government incentives, research and development funding and power conversion/production efficiency improvement**

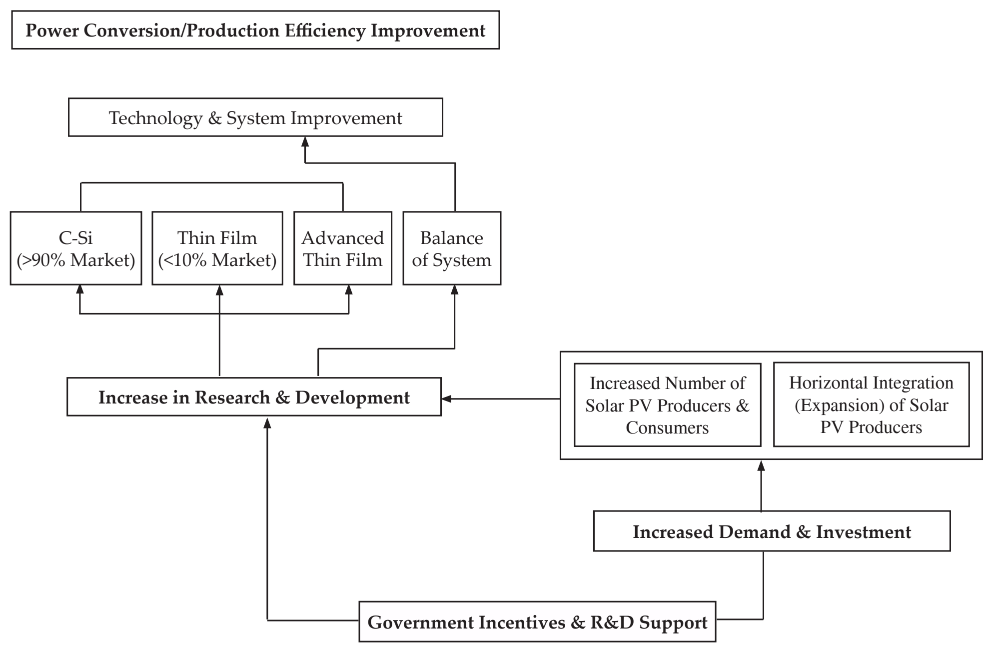



**Table 3.5: Research and development expenditure for a sample of integrated solar PV firms (EUR)**

| Company | 2007 | 2008 | Annual Increase |
|---|---|---|---|
| Q-Cells | 11,400,000 | 25,200,000 | 121% |
| First Solar | 11,106,208 | 24,639,600 | 122% |
| Sumco Corp | 53,154,865 | 83,217,295 | 57% |
| SunPower Corp | 10,002,942 | 15,813,475 | 58% |
| Solarworld | 10,800,000 | 13,000,000 | 20% |
| REC | 12,590,843 | 24,096,658 | 91% |
| Solarfun | 2,952,841 | 2,123,028 | -28% |
| JA Solar | 452,625 | 3,071,385 | 579% |

Source: Company websites.

Despite pressure on all firms to reduce costs across the board during the financial crisis and recession, it is widely accepted that in order to remain competitive in the long run, companies need to continue to invest in R&D through economic downturns.

As well as company investment in R&D, governments have also provided considerable R&D funding to the sector. A sample of government R&D budgets allocated to a sample of solar PV sectors around the world is provided in Table 3.6 below.

**Table 3.6: Public budgets for the solar PV sector research and development in selected countries in 2007**

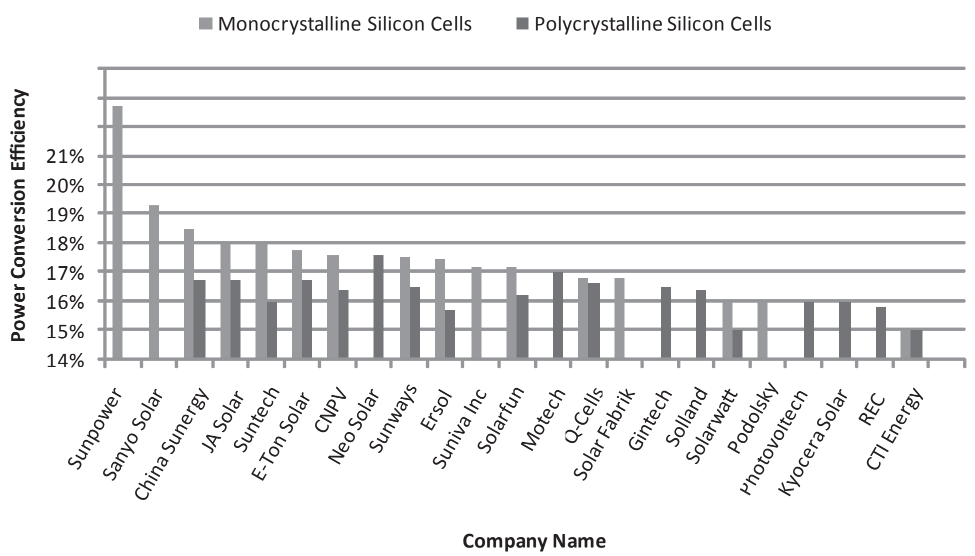
| Country | Million EUR |
|---|---|
| Australia | 4.50 |
| Canada | 3.80 |
| Switzerland | 8.20 |
| Germany | 44.50 |
| Denmark | 3.40 |
| France | 9.10 |
| Great Britain | 11.10 |
| Israel | 0.07 |
| Italy | 5.00 |
| Japan | 28.40 |
| South Korea | 13.40 |
| Mexico | 0.20 |
| Norway | 4.60 |
| Sweden | 2.60 |
| United States | 101.00 |

IEA PVPS, Trends in Photovoltaic Applications, 2008. Available at <www.iea-pvps.org/products/download/rep1_17.pdf>.

## 3.4.2. Crystalline Silicon Conversion Efficiencies

Crystalline silicon is by far the most popular and widely used solar PV material. It has benefited from a comparatively long technological development process, in part due to its growth in parallel with the commercially widespread microelectronic mono-silicon wafer-based technology.

**Figure 3.18: Sample of solar cell and module power conversion efficiencies**




Note: See Appendix 1 for a full list of the detailed power conversion efficiencies of each company.
Source: Company websites.

Crystalline silicon-based solar PV modules are reported to have an efficiency ceiling of approximately 26 per cent[71] with the best commercially available modules currently providing approximately 22 to 23 per cent power conversion efficiency.[72] String ribbon silicon solar cells are reported to have 17 to 18 per cent power conversion efficiency levels.[73] Figure 3.18 illustrates the solar cell power conversion efficiencies achieved by both monocrystalline and polycrystalline silicon solar cells of a sample of companies.[74]

There is an energy loss from solar cells to modules.[75] Sunpower reports a power conversion efficiency of 18.50 per cent for its monocrystalline solar module, compared to the 22.7 percent for its solar cells.

### 3.4.3. Thin-Film Power Conversion Efficiencies

The commercial viability of thin-film technology is starting to be explored, particularly for its use in building-integrated PV (BIPV). Currently it is less efficient than crystalline silicon technology, operating at a power conversion efficiency of between 10 and 15 per cent.[76] However, with the considerable investment in research and development in the field, it is likely that this will improve soon.[77]

Mitsubishi Electric and Sanyo Solar are currently reporting power conversion efficiencies for thin-film solar modules of 10 per cent, with First Solar claiming an efficiency of 10.9 per cent. The Sharp Group currently claims to be leading the field, producing thin-film solar cells with a power conversion efficiency of 13 per cent. However, the company's solar module efficiency is on a par with its main rivals at 10 per cent.

### 3.4.4. Advanced Thin-Film Power Conversion Efficiencies

Advanced thin film differs from other solar PV technologies in its use of alternative materials, some of which are non-semiconductors. Advanced silicon-based materials such as quantum dots, scientists claim, could increase efficiency by as much as 65 per cent.[78] The highest efficiencies achieved to date in laboratory conditions are approximately 42 per cent.[79] However, these extremely expensive solar technologies are currently exclusively used by niche companies and government agencies such as NASA.

### 3.4.5. Solar Trackers

Solar trackers are mechanical systems that manipulate solar modules to optimize their angle and direction relative to the position of the sun. Single-axis trackers can change the angle of the module on either a vertical or a horizontal axis, while dual-axis trackers can manipulate the angle of the module on both vertical and horizontal axes. Whilst solar trackers increase the

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71 Michael Kanellos, Solar Cell Breaks Efficiency Record, CNet News, 6 December 2006. Available at < news.cnet.com/Solar-cell-breaks-efficiency-record/2100-11395_3-6141527.html>.

72 Electronics Design, Strategy, News, 'SunPower touting full-scale solar cell prototype at 23.4% efficiency,' 12 May 2008. Available at <edn.com/blog/450000245/post/10026401.html>.

73 D.S. Kim, et al, String Ribbon Silicon Solar Cells with 17.8% Efficiency, University Centre for Excellent in Photovoltaic Research and Education. Available at <www.ece.gatech.edu/research/UCEP/papers/3world/STRING%20RIBBON%20SILICON%20SOLAR%20CELLS%20WITH%2017.8%25%20EFFICIENCY.pdf>.

74 A complete table of power conversion efficiencies achieved by this sample of companies is provided in Appendix 1.

75 Advent Solar, Whitepape. Available at <adventsolar.com/uploads/File/Advent_Solar_Whitepaper.pdf>.

76 Christine Lepisto, Solar Cheaper than Coal: First Solar's Cadmium Telluride Breakthrough, Tree Hugger, 8 October 2008. Available at <treehugger.com/files/2008/08/cheaper-solar-panels-first-solar.php>.

77 AZOMaterials, Market for Amorphous Silicon Thin-Film Photovoltaics Set to Grow, 28 March 2009. Available at <azom.com/news.asp?NewsID=16221>.

78 Randal Parker, 'Quantum Dots May Boost Photovoltaic Efficiency to 65%,' Future Pundit, 24 May 2005. Available at <futurepundit.com/archives/002789.html>.

79 Darren Murph, 'Baby Steps: New Solar Cell Efficiency Record Isn't Awe Inspiring,' Engadget, 27 January 2009. Available at <engadget.com/2009/01/27/baby-steps-new-solar-cell-efficiency-record-isnt-awe-inspiring/>.

energy output of a solar array, they also increase the total product cost of a solar PV system as well as its operation and maintenance costs.

Research in certain parts of the United States has shown that tracking using a north to south, single axis system increases annual energy output by 21 to 27 per cent compared to a fixed solar array. Dual-axis tracking can improve annual output by between 37 and 43 per cent, almost twice the improvement of single-axis trackers.[80]

Although solar tracking technology alone will not be the driving technological force behind the move to consumer grid parity or commercial solar power price competitiveness, an increase in the efficiency and reliability of solar trackers will contribute to that goal. The tradeoff between the increased total cost of ownership of installing a solar tracking system and the improved total power output it provides may therefore become an important consideration when analysing solar PV technology development.

### 3.4.6. Balance of System Efficiency

The improved efficiency of BOS components within a solar power system contributes to the reduction of system loss. For example, inverters consume a portion of the electricity they convert. In the context of grid parity, the reduced loss from BOS components cannot itself attain the goal. Most inverters operate at their greatest efficiency levels when power output is in a range of 30 to 90 per cent of their maximum capacities.[81] At these rates, efficiency levels of over 97 per cent are possible.[82] During periods of reduced power use inverter efficiency can drop to as low as 50 per cent.

Technological developments continue to be made to improve the efficiency of BOS components and the processes involved in the installation, operation and maintenance of solar power systems. On the whole, however, the most important efficiency improvement in terms of progress towards grid parity is that of solar cells and modules.

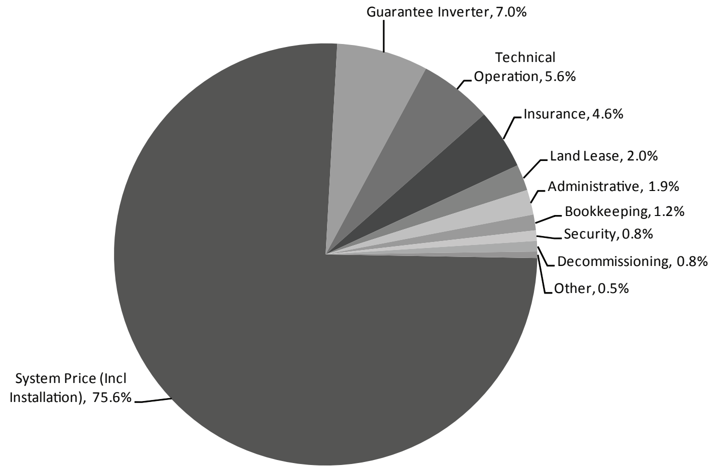
## 3.5. Total Cost Reduction

The total cost of ownership for a solar PV system comprises the cost of purchase, installation, and operation over its useful lifespan. According to Phoenix Solar, for a hypothetical installation in Germany with a EUR 4 million per MW of capacity, the contribution of individual costs to the total cost of ownership (excluding financing cost) is provided in Figure 3.19.

As the power conversion efficiency for crystalline silicon-based solar cells starts to approach its theoretical limit,[83] reducing the total cost of ownership for solar PV systems will become increasingly important in the move towards grid parity and competitive wholesale solar power prices. According to Phoenix Solar, a turnkey system costing 4 million EUR/MW, as per Figure 3.19, can generate solar power at an average cost of 0.27 EUR/kWh. Should the total cost of ownership fall to 1.7 million EUR/MW, this average cost falls to 0.15 EUR/kWh. The contribution of total system cost to total cost of ownership is approximately 75 per cent. Given this, a reduction in total system cost would result in a significant reduction in total cost of ownership.

80 SEPA, PV Basics. Available at <www.solarelectricpower.org/index.php?page=basics&subpage=pv&display=facts>.
81 Northern Arizona Wind and Sun, DC Inverter FAQ. Available at <www.solar-electric.com/solar_inverters/inverters_for_solar_electric.htm>.
82 Inverter Efficiency. Available at <www.101iq.com/infoinve.htm>.
83 European Photovoltaic Platform, Introduction to PV. Available at <www.eupvplatform.org/index.php?id=47>.

**Figure 3.19: Total cost of ownership breakdown over 20 year system lifespan**




Source, Johannes Stierstorfer, Phoenix Solar AG, 5th European PV Industry Forum, Total Cost of Ownership (TOC) – Perspective on PV Competitiveness, September 2008. Available at <www.epia.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/EPIA_docs/documents/23EUPVSEC/Presentations/IF_3_2_Stierstofer.pdf&t=1246361660&hash=7cbb668e19d2c198e1dfe7ca7397bbe5>.

As discussed in Section 2.2, government incentives offered to solar power generators are the drivers behind growth in demand and investment throughout the sector. Since 2004 incentive-fuelled growth has resulted in the emergence of internal and external economies of scale through the increase in the number of new entrants and consumers in the sector, and the horizontal integration and expansion of the industry incumbents. Production capacity in the sector has therefore increased, and improved manufacturing processes have been adopted in response to greater competition. Equally, the cost of installation for solar PV systems has fallen, and will continue to fall as the expertise required is dispersed and demand for solar PV systems grows.

At the same time, as the industry has matured, many firms have adopted vertical integration strategies to exploit the strategic and cost-saving benefits of synergies arising from operating at different stages under the same umbrella in the solar PV industry's value chain. Figure 3.20 provides an illustration of the relationship between government incentives, the expansion of the solar PV industry, and the cost reduction of solar PV systems.

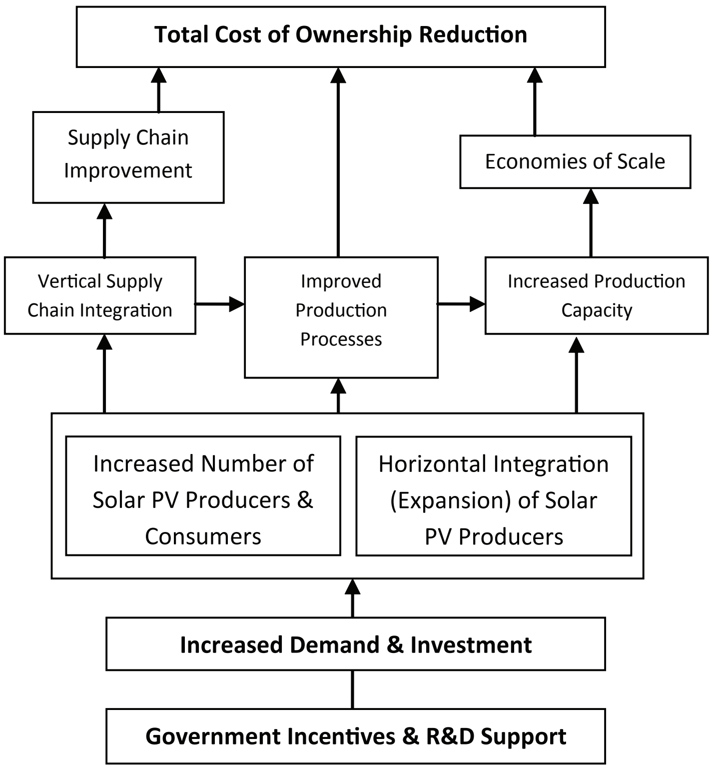
### 3.5.1. Vertical Integration

Vertical integration is defined as the control of one company or group over the upstream supply of its inputs and the downstream sales and distribution of its outputs. A limited interpretation of vertical integration considers only a firm's complete ownership control over different stages of the value chain. This is achieved either through acquisition of a company by another, or through the expansion of a company's production and manufacturing business lines. For the purposes of this report, however, vertical integration will refer to the ultimate operational control a company or group has over business units or group companies at different stages of the value chain. This more inclusive interpretation allows for integration to include joint ventures and minority investments, which can provide the strategic benefits of integration without total ownership control.

From 2006 to the middle of 2008, the solar PV sector in Europe experienced a dramatic growth in demand, investment and installed capacity. This was followed by a sudden and widespread fall in both demand and investment in 2009, largely as a result of the global financial crisis, recession and plunge in oil prices. Through this period various strategic approaches were adopted by both new entrants to the market and more established companies.

Some large companies in the sector, such as Solarworld, employ a strategic approach focussed on integration through multiple parts of the value chain, while various other companies have integrated to a lesser extent, concentrating on one or two upstream and/or downstream value chain segments. A number of large firms such as Dow Corning, through their joint venture subsidiary, Hemlock Semiconductor, a producer of silicon feedstock, have chosen to specialise in one segment of the solar PV value chain. At the same time, multiple new entrants have appeared in the market, particularly downstream in the value chain, aiming to benefit from high levels of demand for solar PV modules.[84]

**Figure 3.20: Relationship between government incentives and total cost of ownership of solar power systems**




### *3.5.1.1. Benefits of Vertical Integration in the Solar PV Sector*

The strategic rationale used to support a firm's decision to embark on the often costly and complex process of vertical integration varies and has changed over time. Vertical integration was originally considered purely as a means of securing internal economies of scale, however during the early to mid-20th century, it became a means of securing access to scarce or costly inputs.[85]

84 Fiona Harvey et al, 'Feeling the Heat,' Financial Times, 3 June 2009. Available at <www.ft.com/cms/s/0/d25b2d04-4fd5-11de-a692-00144feabdc0.html>.
85 Economies of Scale. Available at <tutor2u.net/business/gcse/production_economies_of_scale.htm>.

More recently vertical integration has been employed as a more sophisticated strategic tool. Modern integration strategies aim not only to establish economies of scale and secure inputs, but also to reduce the relative bargaining power of suppliers and/or buyers. This lowers total product cost by establishing and developing synergies between stages in the value chain, and facilitates access to both upstream and downstream profit margins. The benefits offered by vertical integration are particularly important in times of lower industry demand when fierce price competition results in narrower margins at every stage of the value chain.[86]

In the case of the solar PV value chain, the concentration of silicon supply in the hands of a relatively small number of large suppliers weakens the buying power of downstream solar cell and solar module producers. Trina Solar recently announced that it is concerned about its ability to secure raw materials from a limited number of suppliers. As the global recession affects companies in the sector, Trina Solar fears some of its suppliers may go out of business entirely. Related to this, both Trina Solar and JA Solar have stated that they face considerable credit risk due to the requirement for prepayment on certain raw material supply contracts. Furthermore, the volatility of polysilicon prices has meant that long-term supply contracts at pre-agreed prices may prove to be unexpectedly costly as polysilicon prices have fallen sharply and shorter-term contracts may offer much lower prices. Many solar companies have announced that they are now re-negotiating their long-term contract agreements. As a result, upstream integration has emerged as a desirable strategic goal for many firms attempting to secure a greater control over traditionally scarce and high-priced crystalline silicon and thereby reduce associated price volatility. In addition to the greater security of supply, upstream integration allows solar PV firms to monitor and maintain quality standards over different stages of the value chain, thereby reducing testing and transaction-related costs.

Integrated solar PV firms that are able to source a high proportion of raw materials from within their own stable of companies have managed to tailor and standardise manufacturing and distribution systems to reduce the need for expensive packaging materials, and lower the cost of shipping-related breakages.[87] Vertical integration has allowed firms to shorten production cycles and use working capital more efficiently. Upstream solar PV integrators have also benefited from shared technical and financial knowhow at multiple stages in the value chain.

Downstream integration has emerged as a desirable strategy for solar PV firms to establish greater access to larger markets and the relatively high margins achieved through the sale of solar modules and solar project development. An example of the high profitability offered by solar system product sales is SunPower's 32 per cent gross profit margin on revenues from its components segment in the year ending December 2008.[88]

### *3.5.1.2. Risks of Vertical Integration in the Solar PV Sector*

The main risk inherent in vertically integrating is the shift away from a firm's core competencies. A vertically integrating firm will be required to manage a series of manufacturing processes in which it may previously have had limited or no involvement. This shift of a firm's resources to manage a broader portfolio of interests can result in the weakening of its original competitive position within a single segment of the industry value chain.[89] Where previously it may have been able to concentrate on producing high quality modules for a limited number of system integrators, a solar module producer looking to expand into system integration and project

86 PES Europe, The Advantages of Vertical Integration. Available at <www.pes.eu.com/assets/articles/096_TrinaSolar%5B1%5D.pdf>.
87 Trina Solar, Form 20-F. Available at <ccbn.10kwizard.com/cgi/convert/pdf/TrinaSolarLtd20F.pdf?ipage=6292978&num=-2&pdf=1&xml=1&cik=1382158&odef=8&rid=12&quest=1&xbrl=0&dn=2&dn=3>.
88 SunPower, Annual Report 2008. Available at <files.shareholder.com/downloads/SPWR/653643352x0x281930/57412633-dec6-4e27-b9e5-2c647c355a19/SPWR_2008AR.pdf>.
89 PV Group, Solar PV Supply Chain Presentation, March 2009. Available at <www.slideshare.net/joeberwind/supplychain-presentation06-mar-090130pm>.

development may, for instance, encounter problems in adapting its marketing strategy to reach a different customer base. Similarly, a solar cell or module manufacturer looking to integrate vertically upstream may struggle to adapt to the very different production methods and supplier demands involved in silicon ingot and wafer production.

Many of the cost and efficiency benefits of vertical integration are lost when production capacity and demand are inaccurately matched. As demonstrated by the enormous difference between the average long-term contract price of 60 to 65 USD/kg of polysilicon during 2008 and the peak spot price of almost 500 USD/kg in the same year, the premium on short-term purchasing can be extremely high. This is amplified in the case of a vertically integrated firm as capacity mismatches can ripple through an entire production cycle.

In the wake of the global financial crisis and recession, capacity balancing will be of increasing concern to integrated solar PV firms. As demand for solar PV systems in Europe has fallen following the peak demand years of 2007 and early 2008, integrated firms need to lower their upstream production output and capacity to balance lower demand in order to avoid over-supply and even greater downward pressure on market prices. The converse is also true, as the need to anticipate when, and to what extent, demand for solar power systems will recover will be critical in matching upstream capacity with rising downstream demand.

Another potential disadvantage to vertical integration in the solar PV sector is the cost of implementing any radical change of product offering or production technology. By maintaining a controlling interest in different stages in a value chain, many integrated solar PV firms are susceptible to the industry-changing emergence of a disruptive technology. Given the significant cost and time required to change multiple processes within a large organisation or to divest itself of any redundant interests it holds, a firm that is able to develop a radically more efficient solar cell, or a more cost effective production method may hold a strategic advantage over larger, more organisationally cumbersome rivals. This risk is, to an extent, mitigated by the investment in research and development by incumbent firms in the sector,[90] (see section 3.4.1), which are leading in the development of new solar PV technologies.

## 3.5.2. Analysis of Strategic Approaches to Vertical Integration

### *3.5.2.1. Methodology*

The effects of the global financial crisis are now significantly affecting the solar PV sector and the combination of less available investment capital with lower demand for solar power systems is likely to have a dramatic effect on the size and number of firms in the solar PV industry. In the next few years large firms with high levels of debt on their balance sheets may be forced to either divest of company assets at different stages of the value chain (value chain disintegration) or to merge with larger, more financially secure competitors. Similarly, many smaller firms are likely to fail and either declare bankruptcy or be acquired by larger integrated firms or healthier, small competitors.

In this context, an analysis of the solar PV value chain can provide a valuable insight into the current state and likely evolution of the European solar PV sector. An accurate quantitative analysis of vertical integration in any value chain is extremely difficult. This is particularly true for the rapidly changing European solar PV sector. Since 2004, a vast number of new solar PV firms, particularly downstream in the value chain, have emerged throughout Europe in an attempt to exploit generous government incentives,

90 Trina Solar, Form 20-F. Available at <ccbn.10kwizard.com/cgi/convert/pdf/TrinaSolarLtd20F.pdf?ipage=6292978&num=-2&pdf=1&xml=1&cik=1382158&odef=8&rid=12&quest=1&xbrl=0&dn=2&dn=3>.

making the establishment of a reliable sample of companies particularly difficult. Many companies have already failed and been bought or merged.

An additional complication arises in trying to clarify the national origin of companies that are relevant to an analysis of the European solar PV sector. Many companies that have a strong interest in the European solar PV sector are not based in Europe, but may have investments or long-term supply contracts with European firms. This report therefore includes in its sample the largest solar PV companies in the world which maintain a considerable direct commercial interest in the European solar PV market.

The final sample of 108 companies active in Europe is derived from a number of sources including the European Photovoltaic Industry Association's membership directory.[91] This sample includes large, established firms as well as smaller firms, and is intended to provide a reliable indicative sample of firms operating at each stage in the value chain as well as others active at multiple stages. To assess the extent of vertical integration of each sampled company or group, this report classifies each according to which segments of the solar PV value chain it can clearly be shown to operate directly in, or in which it has considerable investment and/or operational influence.

Table 3.7 shows the number of companies operating at each stage of the solar PV value chain, as derived from the sample of 108 firms.

**Table 3.7: Number of companies active in each segment of the value chain**

| Value Chain Segment | Number of Active Firms | Percentage of Total Sample |
|---|---|---|
| Feedstock | 20 | 19% |
| Ingots | 29 | 27% |
| Wafers | 33 | 31% |
| Cells | 43 | 40% |
| Modules | 53 | 49% |
| Project Development, System Integration, BOS production | 61 | 56% |

See Appendix 2 for a full list of the companies sampled.

Where available, each company's revenue and operating profit results are included in an attempt to give an indication of the relative scale and profitability of each firm.[92] There are obvious limitations to this approach, particularly given that many companies do not exclusively produce solar materials, components or systems and include multiple business segments in total revenue figures. The value of each total revenue figure therefore lies in providing an indicative representation of the overall size of each company relative to any other. Similarly, operating profit figures are included to provide a comparative, indicative representation of the profit levels achieved by different firms relative to each other, and between groups of companies employing different vertical integration strategies.

### *3.5.2.2. Results*

Four distinct strategic approaches to vertical integration have been identified amongst companies in the solar PV sector:

- Specialists: firms operating in a single segment of the value chain

91 EPIA, Members Directory. Available at <www2.epia.org/New2009/Members_2009a.asp>.
92 Operating profit figures are provided as indicative, pre-tax profit measures and are not standardised as EBIT, EBITDA or other measure.

- Specialist integrators: firms operating in two segments of the value chain, in closely related activities
- Partial integrators: firms operating in three or four segments of the value chain
- Full integrators: firms that have integrated to control five or six segments of the value chain.

Table 3.8 shows the number of companies adopting each integration strategy.

### Table 3.8: Percentage of companies sampled adopting each strategic integration approach

| | Number of Companies | Percentage of Total Sample |
|---|---|---|
| **Specialists** | 50 | 46% |
| **Specialist Integrators** | 21 | 19% |
| **Partial Integrators** | 22 | 20% |
| **Full Integrators** | 15 | 14% |
| **TOTAL** | **108** | **100%** |

Note: The operating profit and operating revenue resulting from different vertical integration strategies is presented in Table 3.9.

### Table 3.9: Operating revenue and operating profit from different vertical integration strategies

| | Total Operating Revenue | Total Operating Profit | Average Operating Revenue | Average Operating Profit | Percentage Profit Margin |
|---|---|---|---|---|---|
| **Specialists** | 36,151,056,081 | 3,775,028,549 | 1,095,486,548 | 114,394,805 | 10.44% |
| **Specialist Integrators** | 6,448,824,283 | 414,319,340 | 460,630,306 | 29,594,239 | 6.42% |
| **Partial Integrators** | 38,562,854,810 | 210,859,581 | 1,928,142,741 | 10,542,979 | 0.55% |
| **Full Integrators** | 45,200,354,625 | 2,387,438,668 | 3,228,596,759 | 170,531,333 | 5.28% |
| **TOTAL** | **126,363,089,799** | **6,787,646,138** | **1,560,038,146** | **83,798,100** | **5.37%** |

Note: Average operating revenue and average operating profit figures are skewed by the very large conglomerate holding companies which do not publish independent results for their solar PV businesses. They are included to provide an indicative comparative reference.

Each strategic approach is analysed according to a number of key issues, which contribute to the strategic and financial benefits or costs of integration. These include:

- Barriers to entry and economies of scale
- Cost and security of supply of material inputs
- Cost saving and technology improvement offered by synergies between value chain segments
- Profit margins in different segments of the value chain.

### *3.5.2.2.1. Strategic Approach 1 – Specialists*

Specialist firms are defined as those active in only one segment of the value chain. Of the 108 companies sampled for this report 50 are specialist firms, of which 33 published complete annual financial statements. The summarised results derived from the financial statements of specialist companies are shown in Table 3.10.

**Table 3.10: Results from annual financial statements of specialist companies**

| Specialists | Feedstock | Ingots | Wafers | Cells | Modules | System Integrators | TOTAL |
|---|---|---|---|---|---|---|---|
| Number of Firms | 6 | 0 | 0 | 7 | 7 | 30 | **50** |
| Average Annual Operating Revenue | 3,978,577,115 | - | - | 254,898,091 | 105,147,912 | 806,010,573 | **1,095,486,548** |
| Average Annual Operating Profit | 274,988,814 | - | - | 16,679,842 | 6,609,114 | 127,753,832 | **114,394,805** |
| Average Annual % Profit | 6.91% | - | - | 6.54% | 6.29% | 15.85% | **10.44%** |

Notes: For full company listing see Appendix 3

**Fragmentation**

Fragmentation has been a feature of the solar PV sector for the last five years. As shown Table 3.7, the greatest industry fragmentation in the solar PV sector occurs downstream, where the barriers to entry for new entrants are comparatively low due to the relatively small required capital investment and highly labour intensive nature of module production, solar PV system assembly and installation.[93] Of the sample of specialist companies, by far the greatest in number were those active in project development, system integration and BOS production. Furthermore, as detailed in Table 3.7, of the total sample of all 108 companies covered in this report, 56 per cent were involved in some form of system integration, project development and/or BOS production.

For small solar PV systems, system integrators and BOS producers benefit from the relatively low costs of BOS input materials and labour due to most BOS components, such as inverters, now being widely available from a number of competing stockists and distribution outlets. Local knowledge is therefore increasingly a source of competitive advantage for small-scale developers and system integrators. This is, however, a relatively weak barrier to entry for new entrants.

Despite the likely failure or acquisition of many smaller European developers and system integrators as a result of the global financial crisis and recession, fragmentation at this downstream stage of the value chain is likely to continue. With greater supply capacity throughout the industry, the availability of cheaper solar modules and BOS components will continue, lowering the barriers to entry in this value chain segment. As grid parity approaches and demand for small-scale installations increases, it can also be expected that there will be an increase in the demand for, and therefore the number of, trained solar PV system installers. It is likely that this will in turn contribute to the ongoing fragmentation of the small-scale system integrator value-chain segment.

93 Trina Solar, Form 20-F. Available at <ccbn.10kwizard.com/cgi/convert/pdf/TrinaSolarLtd20F.pdf?ipage=6292978&num=-2&pdf=1&xml=1&cik=1382158&odef=8&rid=12&quest=1&xbrl=0&dn=2&dn=3>.

#### Consolidation

By contrast, there are a number of specialist large-scale project developers and system integrators, such as AES Solar Energy and SMA Solar Technologies. Whereas the barriers to entry for small-scale solar system integration are relatively low, for larger solar arrays the project development and BOS costs are considerable. Large-scale solar power project development involves the costly and time-consuming process of securing project planning permission, retaining skilled project managers and the financing of considerable material, land and labour inputs. For this reason large-scale solar installations have traditionally been developed by large engineering and utility companies.

It is inevitable that falling prices and lower demand will tighten the profit margins of integrated solar PV firms and require them to focus on their core competencies of production-cost reduction and improved power conversion efficiency. As a result, large-scale solar power development and operation is likely to continue to be dominated by the large solar PV companies.

#### Upstream barriers to entry

The concentration of the majority of polysilicon production under the control of a few large producers is largely the result of the high barriers to entry provided by economies of scale and the high cost of silicon processing machinery. All of the top five specialist silicon feedstock producers are part of diversified conglomerates with substantial financial resources and technical expertise in activities related to silicon feedstock production. As silicon prices begin to fall, these capital cost-related barriers to entry will be heightened due to longer payback periods and smaller margins.

#### Profitability

Given that many specialist solar PV companies are new market entrants or relatively small, a high proportion does not publish their annual financial results. Of those who do, it is interesting to note that a relatively high proportion were profitable in 2007 or 2008. This is almost certain to change by the year end 2009/10 as a result of the global recession and excess supply capacity throughout the value chain.

### *3.5.2.2.2. Specialist Company Profiles*[94]

#### AES Solar Energy BV

| **AES Solar Energy BV** | | |
|---|---|---|
| Project Developer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 11,819,652,839 | 2,023,389,232 | 17.12% |
| http://www.aes-solar.com | | |

AES Solar Energy BV is a systems developer, owner and operator of utility-scale solar installations.[95] Formed in March 2008, the company is the product of a joint venture between the AES Corporation and Riverstone Holdings LLC. AES Solar will receive a total investment of USD 1 billion (EUR 716.4 million) over five years.

94 Top 20 in terms of Operating Revenue. Unless otherwise indicated, all information comes from companies' websites.
95 Information from Greentech Focus. Available at <www.greentechfocus.com/>.

By the end of 2008, the joint venture had over 200 MW of solar projects developed throughout Europe, in addition to eight operational solar power plants operating in Spain totalling 24 MW. During Q1 2009 this total increased by 8 MW to 32 MW. In mid-2008, AES Solar reconsidered many project plans in order to preserve liquidity. Nevertheless, the company secured non-recourse financing for a USD 90 million (EUR 64.5 million) solar energy project in Spain. In May 2009, AES Solar entered into an exclusive supplier framework agreement with Yingli Green Energy who will supply polycrystalline PV modules for projects over the next three years.[96]

### Mitsubishi Materials

| **Mitsubishi Materials** | | |
|---|---|---|
| Silicon Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 10,943,846,577 | 269,993,207 | 2.47% |
| http://www.mmc.co.jp/corporate/ja/index.html | | |

Mitsubishi Materials is part of the Mitsubishi group and was formed in 1990 with the merging of Mitsubishi Metal and Mitsubishi Mining and Cement. Its activities include the manufacture of high purity polycrystalline silicon. Along with Dow Corning and Shin-Etsu Handotai, Mitsubishi Materials holds a stake in the Hemlock Semiconductor joint venture.[97]

In 2008 the company reported that it would invest JPY 33.5 billion (EUR 254.9 million) in order to boost the output capacity of polysilicon to 4,300 tonnes by 2011.[98] However, in February 2009 Mitsubishi Materials announced revised business projections for the 2008-2009 business year. This included a 46.2 per cent decrease in operating profit due to a global decline in demand.

### Dow Corning / Hemlock Semiconductor

| **Dow Corning / Hemlock Semiconductor** | | |
|---|---|---|
| Silicon Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 4,008,531,921 | 543,321,565 | 13.55% |
| http://www.hscpoly.com | | |

Hemlock Semiconductor (a joint venture, majority owned by Dow Corning) is the largest producer of polysilicon, in terms of production capacity, in the world. Dow Corning is independently a large producer of polysilicon feedstock.

Production capacity in 2007 was 10,000 tonnes, and it is due to increase to 36,000 tonnes by 2010. This is largely due to a USD 2.2 billion (EUR 1.56 billion) investment in production facilities as announced towards the end of 2008. This investment includes a USD 1 billion

96 Mark Osborne, 'AES Solar adds Yingli Green to Exclusive Supplier Base, PVTEch, 15 May 2009. Available at <www.pv-tech.org/news/_a/aes_solar_adds_yingli_green_to_exclusive_supplier_base/>.
97 Sile McMahon, 'Hemlock Semiconductor Starts Production,' PV Tech, 3 June 2008. Available at <www.pv-tech.org/news/_a/hemlock_semiconductor_starts_production_at_new_polysilicon_facility/>.
98 'Mitsubishi Materials to Boost Silicon Production, Reuters, 13 March 2008. Available at <www.reuters.com/article/rbssIndustryMaterialsUtilitiesNews/idUST28529520080314>.

(EUR 700 million) expansion of an existing plant in Michigan, and a new USD 1.2 billion (EUR 850 million) polysilicon plant based in Tennessee.[99]

**Tokuyama Corporation**

| Tokuyama Corporation | | |
|---|---|---|
| Silicon Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 2,312,317,297 | 174,442,016 | 7.54% |
| http://www.tokuyama.co.jp/eng/ | | |

Tokuyama Corporation is a diversified material production company, founded in 1918. Along with its other business lines, the company produces silicon feedstock for the solar PV industry. Towards the end of 2008, Tokuyama Corporation announced that it would be building its second silicon production plant in Malaysia with an annual output capacity of 3,000 tonnes. The annual output capacity at the firm's existing facility in Japan stood at 5,200 tonnes in 2008, and will rise to 8,200 tonnes by mid-2009.

In February 2008 the company announced a revised performance forecast for the 2008-2009 fiscal year. This included a decrease in net sales of 7.4 per cent to JPY 306,500 million (EUR 2.2 billion). The anticipated drop in performance is the result of the worldwide economic recession and a downward trend in demand for their products.

**OCI Chemical**

| OCI Chemical | | |
|---|---|---|
| Silicon Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 1,617,870,714 | 280,718,934 | 17.35% |
| http://www.ocichemical.com/ | | |

OCI Chemical (previously known as DC Chemical Co. Ltd., until April 1, 2009) is a diversified chemicals and materials company based in South Korea. Its business interests cover the production of more than 40 products from inorganic chemicals to petro and coal chemicals.

OCI Chemical moved into polysilicon production in 2008 and has rapidly embarked on an expansion process. In addition to increasing the output of their existing polysilicon-manufacturing plant in Gunsan from 5,000 tonnes to 6,500 tonnes, two additional plants are currently under construction. The first of these, with an annual output capacity of 10,000 tonnes, will come online in Q3 2009. The second, which represents a KRW 880 billion (EUR 518 million) investment, with an annual capacity of 10,000 tonnes, is due to be completed by Q1 2010. Much of this expansion is being funded through prepayments from long-term supply agreements and internal funds.

**Elkem**

Elkem is a specialist producer of polysilicon feedstock for the solar PV industry, and describes itself as one of the world's leading companies for environment-friendly production of metals

99 Mark Osborne, 'Hemlock Semiconductor Starts Construction of a New US1.2 Billion Polysilicon Plant,' PV Tech, 15 December 2008. Available at <www.pv-tech.org/news/_a/hemlock_semiconductor_starts_construction_of_new_us1.2_billion_polysilicon_/>.

and materials. It is owned by the large Norwegian company Orkla, which purchased the US firm Alcoa's 46.5 per cent stake for USD 870 million (EUR 616 million) in 2005 taking Orkla's stake to 97 per cent.

| **Elkem** | | |
|---|---|---|
| Silicon Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 1,010,319,066 | 106,468,348 | 10.54% |
| http://www.elkem.com | | |

The move towards producing high-purity silicon for the solar industry began in 2006 following the announcement of a NOK 2.7 billion investment (EUR 308 million) for the construction of a manufacturing facility in Kristiansand, Norway, which became operational at the end of 2008.

### SMA Solar Technology AG

| **SMA Solar Technology AG** | | |
|---|---|---|
| BOS Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 694,000,000 | 167,000,000 | 24.06% |
| http://www.sma.de/ | | |

SMA Solar Technology AG (formally known as SMA Technologie AG until February 2008), together with its 10 international subsidiaries, develops and produces PV inverters for residential, commercial and off-grid applications. The company claims to hold approximately 38 per cent of the market share. SMA Solar Technology has the largest solar inverter manufacturing plant in the world, located in Kassel, Germany and is planning expansion into the United Arab Emirates and Portugal.

The company can boast holding the world record for solar inverters with an efficiency level of 98 per cent and reported record financial results for 2008, with sales doubling to EUR 682 million. There has, however, been a 25 per cent drop in sales in Q1 2009 compared to Q1 2008.

### JA Solar

| **JA Solar** | | |
|---|---|---|
| Solar Cell Manufacturer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 588,408,355 | 74,580,759 | 12.68% |
| http://www.jasolar.com/ | | |

JA Solar is a specialist solar cell manufacturer first established in July 2006. Recent activity includes a 60 MW solar cell supply contract with Solar Power until the end of 2009.[100] The company has also launched an ambitious vertical expansion programme,

100 Sile McMahon, 'Solar power Inc Places 60 MW Solar Cell Order,' PV Tech, 5 January 2009. Available at <www.pv-tech.org/news/_a/solar_power_inc._places_60mw_solar_cell_order_with_ja_solar/>.

with the start of construction of its USD 100 million (EUR 72 million) ingot, cell and module facility in Yangzhou, China. The plant will increase JA Solar's annual capacity by 300 MW, bringing it to a total of 875 MW by the end of 2009.[101]

The company recently posted a Q1 2009 loss, blaming a significant reduction in demand for its products as a result of the global recession. This is due largely to cutbacks at BP Solar, who were responsible for around 25 per cent of JA Solar's revenue.[102] Revenue was posted as RMB 231.7 million (EUR 24.9 million) which is a decrease of 79.4 per cent from RMB 1.1 billion (EUR 118 million) in Q1 2008. JA Solar has subsequently stated that it will not give guidance on its 2009 revenue or production until there is a change in conditions in the global solar market.

### Goldbeck Solar GmbH

| **Goldbeck Solar GmbH** | | |
|---|---|---|
| Project Developer | | |
| Financial Year 2007 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 550,000,000 | N/A | N/A |
| http://www.goldbeck.de/solar/de/ | | |

Founded in 2001, Goldbeck Solar GmbH is a subsidiary firm of the construction group Goldbeck. The company specialises in PV projects for commercial and industrial facilities. The firm is the leading company for PV installations on industrial buildings in Germany.

During January 2009, Goldbeck Solar completed a sales agreement stating that Yinlgi Green Energy will supply a minimum of 15 MW of PV modules to Goldbeck Solar through 2009, with the option of an additional purchase of 58MW. The company also has a supply agreement in place with Signet Solar

### Phoenix Solar

| **Phoenix Solar** | | |
|---|---|---|
| System Integrator | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 402,494,000 | 33,823,000 | 8.40% |
| http://www.phoenixsolar.com/ | | |

Phoenix Solar describes itself as a leading solar systems integrator involved in the planning, building and operation of large solar power plants. The company has subsidiaries operating in Spain, Singapore, Greece and Australia. In July 2008, the company took over an Italian systems integrator, RED 2002 Srl. In order to limit its dependence on silicon-based solar cells, Phoenix Solar has increased its procurement and focus on thin film to 57.2 per cent of total solar cell procurement in 2008. This figure is likely to increase to approximately 60 per cent in 2009.[103]

101 Mark Osborne, 'JA Solar Starts Construction of a New Integrated Solar Cell Plant,' PV Tech, 22 April 2009. Available at <www.pv-tech.org/news/_a/ja_solar_starts_construction_of_new_integrated_solar_cell_plant/>.

102 Mark Osborne, 'JA Solar to Miss 2009 Revenue,' PV Tech, 20 May 2009. Available at <www.pv-tech.org/news/_a/ja_solar_to_miss_2009_revenue_and_production_guidance/>.

103 Mark Osborne, 'Phoenix Solar Expects Future Growth in 2009,' PV Tech, 18 March 2009. Available at <www.pv-tech.org/news/_a/phoenix_solar_expects_further_growth_in_2009_60_thin_film_installation_targ/>.

Current expansion includes construction of a PV power plant with a 5.8 MW peak output for the Envos Group in the Rhineland-Palatinate region of Germany. The company has reported that orders rose by 121 per cent to EUR 248 million by 31 March 2009. However, revenue for Q1 2009 has declined by 50.3 per cent to EUR 8.2 million compared to Q1 2008. Phoenix Solar has also extended its contractor agreement with KG Allgemeine Leasing GmbH & Co. until 2011. The value of the agreement may be more than EUR 375 million.

### Aleo Solar

| **Aleo Solar** | | |
|---|---|---|
| Solar Module Manufacturer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 384,588,000 | 23,783,000 | 6.18% |
| http://www.aleo-solar.de | | |

Founded in 2001, Aleo Solar (formally known as S.M.D Solar-Manufaktur Deutschland GmbH & Co. KG until 2005) produces solar modules, predominantly utilising solar cells purchased from Q-Cells. This procurement agreement amounts to 1,270 MW of cells, with the option to order a further 1,000 MW, between 2008 and 2019.[104] Aleo Solar has a further long-term agreement with Ersol Solar Energy AG for the provision of 250 MW of crystalline solar cells between 2008 and 2020. This deal is estimated to cost USD 3 billion (EUR 2.15 billion). The company's silicon-based module production capacity was 100 MW (90 MW in Germany and 10 MW in Spain) by the end of 2007.

Aleo Solar has announced a joint venture agreement with Sunvim Group Co. to construct a solar module production plant in the Shandong province of China. This will increase module production capacity to 180 MW by the end of 2009. Aleo Solar has taken a 19 per cent stake in thin-film module manufacturer Johanna Solar Technology GmbH. The figures for Q1 2009 show a decline in revenue from EUR 69 million to EUR 3 0.6 million, though expectations for the rest of the year are still high largely due to the company expanding its presence in North America and Greece.

### Gintech

| **Gintech** | | |
|---|---|---|
| Solar Cell Manufacturer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 352,818,487 | 50,048 | 0.01% |
| http://www.gintech.com.tw/en/about.php | | |

Formed in 2005, Gintech is a Taiwan-based solar company specialising in the manufacture of solar PV cells. The company expects that by 2011 its total annual production capacity will reach 1.5 GW, which should make Gintech the third largest solar cell manufacturer in the world.

Since 2006, the company has had a 10-year wafer supply contract with MEMC, originally worth between USD 2.5 and 3 billion (EUR 1.78 and 2.15 billion). In February 2009, MEMC agreed to

104 Sile McMahon, 'Aleo Solar Signs Significant Solar Cell Purchasing Agreement,' PV Tech, 12 March 2008. Available at <www.pv-tech.org/news/_a/aleo_solar_signs_significant_solar_cell_purchasing_agreement_with_q_cells/>.

cut the contract price due to a global drop in the price of polysilicon.[105] In May 2008 ReneSola signed a 525 MW six-year wafer supply agreement with Gintech.[106]

### AEG Power Solutions

| AEG Power Solutions | | |
|---|---|---|
| Balance of System Manufacturer | | |
| Financial Year 2007 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 270,593,000 | -2,018,000 | -0.75% |
| http://www.aegps.com | | |

AEG Power Solutions describes itself as a provider of world-class systems and solutions for industrial, IT, solar and high-tech power controller applications. AEG Power Solutions is the result of a consolidation between Saft Power Systems and AEG Power Supply Systems. AEG provides solar inverters for grid and off-grid solar projects.

### Neo Solar Power (NSP)

| Neo Solar Power (NSP) | | |
|---|---|---|
| Solar Cell Manufacturer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 226,836,021 | 11,201,366 | 4.94% |
| http://www.neosolarpower.com/ | | |

Founded in 2005, Neo Solar Power (NSP) describes itself as a leading manufacturer and developer of high efficiency solar cells. In 2008 revenues from solar cell sales ranked third largest in Taiwan. The company currently has a seven-year wafer supply contract in place with REC from 2009 to 2015, with a total value of USD 442 million (EUR 317 million). NSP and Scheuten Solar Technology GmbH have a five-year solar cell supply contract in place for 2009-2013. This contract, combined with two other contracts, amounts to USD 460 million (EUR 326 million). NSP also has a five-year solar cell supply contract with Canadian Solar, worth USD 500 million (EUR 354 million).

Its current production capacity is 210 MW, though this is expected to increase to 660 MW by 2010 following the completion of a new manufacturing facility. The company aims to achieve an annual production capacity of 1 GW by 2012. Neo Solar currently has an R&D collaboration agreement in place with Centrotherm Photovoltaics AG to improve mass-produced solar cell efficiency levels to over 20 per cent.

### China Sunergy

China Sunergy is one of the leading manufacturers of solar cell products in China as measured by production capacity. Significant contracts include a seven-year wafer supply contract with REWC between 2009 and 2015, worth over USD 400 million (EUR 283 million).[107] China

105 Patricia Johnson, 'MEMC Cuts Wafer Price in Contract,' PV Tech, 18 February 2009. Available at <www.pv-tech.org/news/_a/memc_cuts_wafer_price_in_contract_with_gintech/>.
106 Mark Osborne, 'Gintech Energy to Receive 52 MW,' PV Tech, 14 May 2008. Available at <www.pv-tech.org/news/_a/gintech_energy_to_receive_525mw_of_solar_cells_from_renesola_over_6_years/>.
107 Sile McMahon, 'China Sunergy Taps REC Wafer,' PV Tech, 26 June 2008. Available at <www.pv-tech.org/news/_a/china_sunergy_taps_rec_wafer_for_seven_year_wafer_supply/>.

Sunergy also has a 30 MW sales contract in place with Asola in 2009[108] (a sales contract which is expected to total 480 MW by 2018), along with a 12 MW contract with Ajit Solar[109] and a 25 MW contract with SolarMax Technology.[110] The revenue for Q1 2009 amounted to USD 37 million (EUR 26 million), which represents a 14.4 per cent decrease compared to Q4 2008. Shipments of high efficiency cells (with a conversion efficiency rate over 17 per cent) during Q1 amounted to 8.9 MW, compared with 6.5 MW during Q4 2008.

| **China Sunergy** | | |
|---|---|---|
| Solar Cell Manufacturer | | |
| Financial Year 2007 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 210,723,742 | 220,653 | 0.10% |
| http://www.chinasunergy.com/ | | |

## Systaic AG

| Systaic AG | | |
|---|---|---|
| Project Developer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 202,211,000 | 9,541,000 | 4.72% |
| http://www.systaic.com/ | | |

Systaic AG is a German-based solar energy company that operates in the development, planning and provision of suitable technology for solar projects. The company describes itself as the world's only mass producer of PV generators for car roofs. Their subsidiary, Enerparc, works on the development and installation of large PV power plants.

In October 2008, the company reported a module supply contract with Canadian Solar. This amounts to 60 MW of modules for delivery throughout 2009.[111] In November 2008, the group concluded the sale of their Spanish solar power plants with Eurovoltaic and an end-investor for EUR 70 million. Sales figures between 2007 and 2008 increased six-fold from EUR 31 million (2007) to more than EUR 200 million (2008). The group's sales and earnings figures for 1Q 2009 are ahead of their internal forecasts, with consolidated sales at just over EUR 50 million. Much of this is due to the strong performance of the Systaic Solar Power Plant Division.

## Wagner & Co.

| **Wagner & Co.** | | |
|---|---|---|
| System Integrator | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 166,664,000 | 4,729,000 | 2.84% |
| http://www.wagner-solar.com | | |

108 Sile McMahon, 'China Sunergy to Supply up to 30 MW,' PV Tech, 2 March 2009. Available at <www.pv-tech.org/news/_a/china_sunergy_to_supply_up_to_30mw_of_solar_cells_to_asola_in_2009/>.
109 Tom Cheyney, 'China Sunergy Signs PV Cell Supply Deal,' PV Tech, 29 December 2008. Available at <www.pv-tech.org/news/_a/china_sunergy_signs_pv-cell_supply_deal_with_ajit_solar/>.
110 Mark Osborne, 'China Sunergy Signs New Solar Cell Supply Deal,' PV Tech, 18 March 2009. Available at <www.pv-tech.org/news/_a/china_sunergy_signs_new_solar_cell_supply_deals/>.
111 'Canadian Solar Signs 2009 Sales Contract,' Solar Buzz, 9 October 2008. Available at <www.solarbuzz.com./news/NewsEUCO642.htm>.

Wagner & Co. describes itself as one of the leading solar power companies in Germany, with a history dating back more than 25 years. The company specialises in the manufacture of solar power systems for residential and commercial use. In June 2008, Wagner and US company groSolar, signed two new long-term sales agreements with Evergreen Solar Inc, worth a combined USD 600 million (EUR 425 million).[112]

**Intrakat**

| **Intrakat** | | |
|---|---|---|
| Project Developer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 152,000,000 | 3,900,000 | 2.57% |
| http://www.intrakat.gr/default.asp?pid=1&la=2 | | |

Established in 1987, Intrakat is a Greek solar power developer. Following two decades of growth, the company currently holds a leading position in complex, high technology construction projects, serving both the public and private sectors.

**Juwi Solar GmbH**

| **Juwi Solar GmbH** | | |
|---|---|---|
| Project Developer | | |
| Financial Year 2007 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 147,977,000 | 9,226,000 | 6.23% |
| http://www.juwi.de/solar/angebote.html | | |

Juwi Solar GmbH has completed over 750 solar projects for a total installed capacity of 100 MW. These projects include grid-tied systems operating in Germany, Spain, Italy, and Africa. Major projects include Rote Jahne, a 6 MW project, and Waldpolenz, a 40MW project, both in Germany and expected to be completed by the end of 2009. Waldpolenz will be the largest thin-film solar power plant in the world when it comes online.

**Acciona Solar S.A.**

| **Acciona Solar S.A.** | | |
|---|---|---|
| Project Developer | | |
| Financial Year 2007 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 94,432,000 | 6,511,430 | 6.90% |
| http://www.acciona-energia.com/ | | |

Acciona Solar S.A. is a diversified renewable energy company focussing on renewable electricity development and utility-scale facilities management.

The development and construction of renewable power facilities constitutes the basis of the company's business, and the sale of electricity accounts for a substantial part of its income. It has a particular focus on concentrated solar-thermal power (CSP) and it is expected that by the end of 2010 the company will have four CSP plants operational in Spain, with a combined capacity of 200 MW.

112 'Evergreen Solar Signs Sales Contracts,' Forbes, 18 June 2008. Available at <www.forbes.com/feeds/afx/2008/06/18/afx5130981.html>.

**Table 3.11: Balance of specialist companies sampled**

| Company Name | Value Chain Segment | Financial Year | Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
|---|---|---|---|---|---|
| Econcern - Ecostream International B.V. | System Integrator | 2006 | 90,035,000 | -3,777,000 | -4.20% |
| Solar Ventures S.P.A. | Project Developer | 2007 | 86,354,000 | -735,016 | -0.85% |
| Solland Solar Energy B.V. | Solar Cell Producer | 2007 | 84,235,000 | 4,226,000 | 5.02% |
| Abastecimientos Energeticos S.L | Project Developer | 2007 | 79,678,594 | 7,669,359 | 9.63% |
| Photovoltech | Solar Cell Producer | 2007 | 66,366,939 | 9,800,228 | 14.77% |
| Gunther Spelsberg GmbH + Co. KG | BOS Producer | 2007 | 42,501,000 | 10,234,000 | 24.08% |
| Albiasa Solar Sociedad Limitada. | Project Developer | 2007 | 26,916,000 | 1,103,897 | 4.10% |
| Naps Systems Oy | Project Developer | 2007 | 26,105,359 | 2,605,248 | 9.98% |
| 3S Industries AG | BIPV Module Producer | 2007 | 17,610,702 | 1,755,294 | 9.97% |
| EXEL GROUP S.A. (Solar Division) | Module Producer | 2007 | 16,202,087 | 771,331 | 4.76% |
| Edisun Power Europe AG | Project Developer | 2007 | 4,886,145 | 395,672 | 8.10% |
| United Solar Ovonic Europe GmbH | Module Producer | 2008 | 2,190,860 | 126,831 | 5.79% |
| Aries Solar Termoelectrica S.L. | Project Developer | 2007 | 1,690,376 | -28,853 | -1.71% |
| Na'an Sanjing Silicon | Feedstock Producer | - | N/A | N/A | N/A |
| Solarcentury | Project Developer | - | N/A | N/A | N/A |
| WIP - Renewable Energies | Project Developer | - | N/A | N/A | N/A |
| Energy Solutions S.A. | Module Producer | - | N/A | N/A | N/A |
| Bisol d.o.o. | Module Producer | - | N/A | N/A | N/A |
| BG Solar Panels Ltd. | Module Producer | - | N/A | N/A | N/A |
| Suniva Inc. | Solar Cell Producer | - | N/A | N/A | N/A |
| City Solar | Project Developer | - | N/A | N/A | N/A |
| Meridian Neue Energien GmbH | Project Developer | - | N/A | N/A | N/A |
| Beck Energy | Project Developer | - | N/A | N/A | N/A |
| Tauber Solar | Project Developer | - | N/A | N/A | N/A |
| Gehrlicher Solar AG | Project Developer | - | N/A | N/A | N/A |
| Avanzalia | Project Developer | - | N/A | N/A | N/A |
| Geosol | Project Developer | - | N/A | N/A | N/A |
| Flixsolar | Project Developer | - | N/A | N/A | N/A |
| Solartia | Project Developer | - | N/A | N/A | N/A |
| Idesa | Project Developer | - | N/A | N/A | N/A |

Note: N/A: Not Available.

### *3.5.2.2.3. Strategic Approach 2 – Specialist Integration*

Specialist Integrators are classified as solar PV firms active in two segments of the value chain. Of the 108 companies sampled, 21 are specialist integrators, having either expanded or entered directly into two segments of the solar PV value chain. This limited integration strategy tends to be employed by firms seeking efficiency benefits through the integration of two similar manufacturing processes, or cost reduction and improved access to profit margins at more than one stage in the value chain. Given the limited nature of specialist integration, upstream security of supply benefits are limited.

**Downstream Specialist Integration**

The strategy of limited integration based on similar manufacturing processes in more than one stage of the value chain is pursued predominantly by firms downstream in the value chain, i.e. from the production of solar cells to project development, system integration, and BOS production.

It is surprising that only a relatively small number of solar cell producers also manufacture and assemble solar modules, as it could be expected that the synergies gained through the integration of these processes are significant by matching the physical size and performance characteristics of solar cells with module designs. Similarly, the quality and reliability of solar cells produced in-house is more consistent and predictable than that of third party suppliers, and hence solar module production can be undertaken with less need for individual cell testing. Such testing is a requirement for cells delivered by external suppliers. Many solar cell and module producers have vertically integrated into more than two different segments of the value chain, a stated strategic aim of solar companies such as E-Ton.

Further downstream, larger specialist integrated solar module producers, BOS producers, system integrators and/or developers can benefit from the relatively high margins available. In both small- and large-scale developments a deep understanding of the properties of solar modules and the best practices and materials required when installing the modules, provides both a cost-saving benefit and a technical advantage to downstream specialist integrated firms.

Additional benefits can be gained by downstream specialist integration through increased access to the final customer and therefore a more accurate means of understanding shifts in demand or consumer preference. More accurate market information allows for improved production forecasting and distribution mapping. This greater interaction with end customers also facilitates an improved matching of solar module product development with changing customer preferences or needs. The benefit of direct customer access is gained by downstream specialist integrators without the need for capacity balancing upstream in the value chain, although this limited security of supply is a potential risk.

**Upstream Specialist Integration**

A few producers of polyscrystalline and monocrystalline silicon ingots have invested in the technology required to produce silicon wafers. Both processes involve the physical transformation of silicon material and as such require similar technical know-how of the properties of the material. The benefits of economies of scale from specialising in the production of silicon feedstock are considerable and hence many silicon producers have chosen to remain as specialists.

Of the specialist integrators, only E-ton employs an integration strategy including exclusively solar wafer and solar cell production. This is likely to be a result of the difference in production methods employed at these stages. Solar cell production involves the complex chemical and physical transformation of the silicon wafer, as described in Section 3.1.3, while wafer production most commonly involves the mechanically complex process of slicing up silicon ingots. It would appear that the costs of expanding production capacity to include these two very different processes outweigh the benefit derived by doing so.

**Profitability**

As was the case with the sample of solar PV industry specialists, there are a relatively high proportion of specialist integrators who do not publish their financial results. Of those who do, all but two, Solaire Direct and Conergy, were profitable according to their latest available financial results. Conergy AG released its 2009 results showing a pre-tax loss in 2008/9 of EUR 213 million, an almost identical figure to its pre-tax loss in the 2007/8 financial year.

### *3.5.2.2.4. Specialist-Integrated Company Profiles*

**Atersa SA**

| **Atersa SA** | | |
|---|---|---|
| Module Producer & Project Developer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 1,911,000,000 | 138,000,000 | 7.22% |
| http://www.atersa.com/home.asp | | |

Atersa SA is a Spanish manufacturer and systems developer of solar modules. The company was created in 1983 as a result of the merger between Elecsol and Atesol. Atersa is a 100 per cent owned subsidiary of the Elecnor Group who themselves promote and manage energy and telecom projects. Atersa has a manufacturing facility located in Valencia, and sales offices in Madrid, Valencia, Cordoba and Milan. The company produced 111 MW of modules in 2008, which is an increase of 33.7 per cent from 2007.

**Conergy AG**

| **Conergy AG** | | |
|---|---|---|
| Module Producer & Project Developer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 1,006,200,000 | -212,500,000 | -21.12% |
| http://www.conergy.com/ | | |

Founded in 1998, Conergy AG is a Germany-based manufacturer of solar thermal, PV and wind components. The company has sold more than 800 MW of its solar modules. The company secured a long-term purchase contract with MEMC. However, in April 2009, Conergy became involved in legal action against MEMC due to an alleged number of anti-competitive contractual provisions which Conergy believe invalidate the contract. The company also announced in November 2008 that a planned joint venture with the Korean company LG Electronics would no longer be going ahead. This was attributed to the global financial crisis. There are currently discussions for Conergy to cooperate with General Electric in order to form an Asian renewable energy trust, with the aim of investing a total of USD 250 million (EUR 177 million) over five years.[113]

113 Raphael Minder, 'GE and Conergy Look to Invest,' Financial Times, 15 December 2008. Available at <www.ft.com/cms/s/0/c7a4d4c2-ca48-11dd-93e5-000077b07658.html>.

Conergy has reported that it expects a weak financial year in 2009, largely due to strong subsidies to Chinese manufacturers. This follows the 2008 net loss of EUR 307 million.[114]

Figures for Q1 2009 show a loss before interest and tax of EUR 20.6 million, though this exceeds expectations as analysts had anticipated a EUR 29 million loss.[115] The company is currently undergoing major restructuring.

**First Solar**

| **First Solar** | | |
|---|---|---|
| Thin-film Cell & Module Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 916,667,402 | 341,276,846 | 37.23% |
| http://www.firstsolar.com/ | | |

Founded in 1999, First Solar is a US-based energy company that manufactures thin-film solar cells and modules. It is currently the largest producer of thin-film solar cells in the world. As of March 2009, the company had produced over 1 GW of solar modules since it began commercial production in 2002. By the end of 2009, the company will have the ability to produce more than 1 GW per year due to their 23 solar module production lines in operation.

First Solar are involved with several high-profile solar projects, including supplying PV modules for Australia's largest solar PV installation, along with a 53 MW PV power plant to be located near Cottbus, Germany. The company recently announced a Q1 2009 net income of USD 164.6 million (EUR 119.5 million), up from USD 46.6 (EUR 22.9 million) for Q1 2008.[116] In May 2009, First Solar completed an acquisition of OptiSolar's PV project pipeline which will give the company a larger foothold in the US utility segment.

**Solon SE**

| **Solon SE** | | |
|---|---|---|
| Module Producer & Project Developer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 875,319,000 | 57,704,000 | 6.59% |
| http://www.solon.com/cw/en/ | | |

Solon SE, based in Germany, is one of the largest solar module manufacturers in Europe, with subsidiaries in Germany, Austria, Italy, Switzerland and the US. Since 2005, the company has constructed solar power plants with a combined capacity of 130 MW. The firm has plans to increase its presence along the solar value-chain. In December 2008, Solon completed its acquisition of Italian start-up Estelux SRL, which plans to produce solar silicon in Ferrara, Northern Italy. The plant will have an opening annual capacity of 4,000 tonnes by the end of 2010. Total investment amounts to approximately EUR 400 million.

114 Christopher Steitz et al, 'Conergy Sees Strong Industry Growth from 2010,' Reuters, 29 April 2009.. Available at <uk.reuters.com/article/tnBasicIndustries-SP/idUKLT17799820090429>.
115 'Conergy Q1 Operating Loss Beats Expectations,' Reuters, 14 May 2009. Available at <uk.reuters.com/article/oilRpt/idUKLD40096620090514>.
116 'First Solar Q1 Net More than Triples on Strong Rev,' Wall Street Journal, 29 April 2009. Available at <online.wsj.com/article/BT-CO-20090429-719426.html>.

In August 2008, Solon signed a multi-year supply agreement with the US cell manufacturers Suniva. The agreement promises the delivery of USD 500 million (EUR 363.1 million) worth of moncrystalline silicon cells between 2009 and 2012. This was preceded in June with Solon acquiring a strategic stake in the newly formed US company SpectraWatt Inc., which was due to begin delivery of high efficiency solar cells in mid-2009. The company reported Q1 2009 revenue figures down by 76 per cent from last year, to EUR 38.3 million. This downturn was attributed to the unusually harsh German winter, compounded with the difficulty of gaining funding for larger PV projects.

### IBC Solar AG

| **IBC Solar AG** | | |
|---|---|---|
| Module Producer & Project Developer | | |
| Financial Year 2007 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 558,860,000 | 25,243,000 | 4.52% |
| http://www.solon.com/cw/en/ | | |

IBC Solar AG is a German-based solar module manufacturer and developer with a history dating back more than 25 years, and with subsidiaries in Europe and Asia. The company has installed more than 350 MW of PV systems at more than 50,000 solar energy facilities around the world. In March 2009, IBC completed one of the largest solar roof systems in the world, at the cost of EUR 15 million for an output of 3.8 MW.

IBC Solar has a long-term supply contact in place with Ersol to deliver EUR 500 million of crystalline cells between 2008 and 2017. IBC also holds a EUR 871 million dollar contract with Evergreen Solar to provide low-cost String Ribbon solar panels until 2013.

### E-Ton Solar Tech

| **E-Ton Solar Tech** | | |
|---|---|---|
| Wafer and Cell Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 370,369,545 | 34,105,652 | 9.21% |
| http://www.e-tonsolar.com | | |

E-Ton Solar Tech, founded in 2001, is a monocrystalline solar cell manufacturer based in Taiwan. The company is working to accomplish full vertical integration of the solar industry value chain. In 2007, solar cells provided 95 per cent of the firm’s revenues with production capacity reaching 320 MW by the end of 2008, up from 200 MW in 2007. Annual capacity is planned to reach 440 MW in 2009.

To date, E-Ton has entered into a partnership with M.Setek, a Japan-based monocrystalline silicon wafer manufacturer, and it acquired the US silicon wafer supplier Adema in 2007 for USD 153.7 million (EUR 112.6 million). In August 2006, E-Ton also entered into a partnership with the Yulon Group and Hsin Chong Machinery to form Gloria Solar Co. Ltd. for the production of solar cells. Additionally, the company formed a joint venture with LiteOn and other companies in 2007. The new company, Auria Solar, specialises in the manufacture of high-efficiency thin-film solar cells.

### 9REN (Gamesa Solar)

| 9REN (Gamesa Solar) | | |
|---|---|---|
| Module Producer & Project Developer | | |
| Financial Year 2007 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 370,369,545 | 34,105,652 | 9.21% |
| http://www.e-tonsolar.com | | |

Gamesa Solar separated from the Spanish Gamesa Corporation in 2001 and it is dedicated to the PV energy and solar thermal market. In 2008 the First Reserve Corporation acquired Gamesa Solar along with Ener3 for approximately EUR 270 million. These two organisations were subsequently merged to form the 9REN Group. The company manufactures PV panels and develops CSP projects.

To date, Gamesa Solar has installed more than 90 MW in PV systems in Spain, and it has constructed approximately 160,000 m² of solar thermal collectors since 2003. The company's four-year plan includes the construction of 280 MW of PV systems in Spain, 160 MW in Italy and 300 MW of systems planned internationally, by 2012. At the end of 2008, the group formed a joint venture with Pangea Green Energy dedicated to the initial completion of five PV systems in Puglia, southern Italy, of 1 MW each following an investment of EUR 24 million.

### Solarwatt

| Solarwatt | | |
|---|---|---|
| Cell & Module Producer | | |
| Financial Year 2007 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 194,362,000 | 5,433,000 | 2.80% |
| http://www.solarwatt.de/ | | |

Founded in 1993, Solarwatt is a German-based solar module and cell manufacturer. Originally a producer of small modules, the company expanded to manufacture cells in 2005 through its fully owned subsidiary Solarwatt Cells GmbH. However, the company has also signed a supply contract with China Sunergy to supply Solarwatt with 22 MW of solar cells during 2009.[117] The company will be investing heavily in its Dresden module manufacturing plant during the summer of 2009 to increase annual production.

### Tenesol

| Tenesol | | |
|---|---|---|
| Module Producer & Project Developer | | |
| Financial Year 2007 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 144,671,000 | 10,234,000 | 7.07% |
| http://www.tenesol.com/en/index.php | | |

Tenesol (formally known as Total Energie until May 2005) is a solar module manufacturer and systems developer that can trace its origins back to 1983. The company is owned by the

117 'China Sunergy Receives Cell Order from Solarwatt', Solar Buzz, 10 December 2008. Available at <www.solarbuzz.com./news/NewsEUCO692.htm>.

Total and EDF Groups and has subsidiaries across much of Europe, Africa, South America and the Middle East. In order to meet demand, Tenesol has invested substantially in their two production sites in Toulouse and Cape Town. Tenesol has also established Evasol, which specialises in the installation of solar panels for households. Evasol recently completed a capital increase of EUR 2.2 million to fund growth plans.[118] The company recorded a turnover of EUR 193 million in 2008, which is an increase of 45 per cent on 2007.

### Siliken SA

| Siliken SA | | |
|---|---|---|
| Module Producer & Project Developer | | |
| Financial Year 2007 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 135,544,000 | 15,769,000 | 11.63% |
| http://www.siliken.com | | |

Siliken SA are a group of companies based in Spain that specialise in the production of solar modules, and the development of solar installations. The group has subsidiaries in the US, Italy, France and Germany.

In 2005, the company created Siliken Electronics, which manufacture grid connection converters for PV plants. Later, in 2006, the company created Siliken Chemicals which will specialise in the production of silicon when it eventually becomes operational. The aim of this venture is to secure a supply of raw materials. In 2008, the group opened two new module production plants in Tenerife and the US and has plans for further vertical integration.

### Table 3.12 Balance of specialist integrated companies sampled

| Company Name | Value Chain Segment | Financial Year | Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
|---|---|---|---|---|---|
| **Solaria** | Module Producer & Project Developer | 2008 | 119,118,000 | -26,654,000 | -22.38% |
| **Renergies Italia S.p.A** | Module Producer & Project Developer | 2007 | 13,412,411 | 570,169 | 4.25% |
| **Martifer Solar S.A.** | Module Producer & Project Developer | 2007 | 1,747,925 | 29,673 | 1.70% |
| **Solaire Direct** | Module Producer & Project Developer | 2007 | 1,553,000 | -892,000 | -57.44% |
| **Solarpro JSCo.** | Module Producer & Project Developer | | N/A | N/A | N/A |
| **Bangkok Solar Co. Ltd.** | Module Producer & Project Developer | | N/A | N/A | N/A |
| **Pillar JSC** | Ingot & Wafer Producer | | N/A | N/A | N/A |
| **Piritium S.A.** | Ingot & Wafer Producer | | N/A | N/A | N/A |
| **Swiss Wafer** | Ingot & Wafer Producer | | N/A | N/A | N/A |
| **CTI Energy Products** | Cell & Module Producer | | N/A | N/A | N/A |
| **Silcio S.A.** | Cell & Module Producer | | N/A | N/A | N/A |

Note: N/A: Not Available.

118 'Evasol Raises EUR2.2 M,' Aderly Lyon, 29 April 2009. Available at <www.aderly.com/lyon/contents/lyon-economic-news/economic-news-company-development.jsp?lang=2&id=5487&title=News-SOLAR---EVASOL-RAISES-%AC2.2-M>.

### *3.5.2.2.5. Strategic Approach 3 – Partial Integration*

Partial integration refers to solar PV firms that are active in three or four segments of the value chain. Of the sample of 108 companies analysed in this report, partial integration is employed by 22 companies, both upstream and downstream in the solar PV value chain.

**Partial Integration throughout the value chain**

Among the sample of companies, partial integration through three or four stages of the solar PV value chain is common both upstream and downstream in the value chain. It is difficult to distinguish between partial integrators which are in the process of integrating further upstream or downstream along the value chain, and those which have limited their partial integration strategy to their existing value-chain segments.

Fully integrated firms hold an advantage over partially integrated firms by diversifying the risk posed by an economic downturn through their ability to make slight adjustments to their product lines and their control of different stages of the value chain. Partially integrated firms face the risk of being caught between the benefits of integration and the risks posed by exposure to multiple operational demands in different segments of the value chain and a lack of ultimate control over raw materials and final consumer markets.

It is interesting to note that the limited integration approach is adopted by some of the largest firms, in terms of revenue, active in the solar PV industry, such as Sharp, Wacker Chemie, Sumco, MEMC and LDK.

**Profitability**

What is particularly interesting amongst partially integrated firms in the solar PV sector is the relatively high percentage that has run at an operating loss. From the 21 companies that employ this partial integration strategy, approximately 40 per cent either broke even or ran at a pre-tax loss.

From the data gathered from the sample of companies examined, there is no insight offered as to the likely relative profitability of one firm compared to any other using a similar partial integration strategy. In 2008 ReneSolar and PV Crystallox operated at a loss and an impressive profit respectively, despite the fact that they operated in similar upstream segments of the value chain.

It is evident, however, that the worst performing partially integrated companies in 2008 were smaller firms. It is likely that these smaller operations have less diversified business interests or less powerful parent companies. As a result it is probable that they were less protected from the dramatic fall in silicon demand and consequent drop in prices towards the end of 2008, which would have been made worse by the reduction in new investment and lending in the sector from 2008 to early 2009, restricting their ability to make substantial changes to their capital structures.

### *3.5.2.2.6. Top 12 Partially-Integrated Company Profiles*

**Sharp Group**

The Sharp Group began the development of solar cells in 1959, and commenced production in 1963. Production facilities are located in Japan, the UK and the US. In 2004 Sharp was the global leader in solar cell and module production, with a 27.1 per cent market share, although it has since been overtaken by Q-Cells. In 2001 cell production capacity increased from 94 MW to 150 MW in 2002. This again rose to 400 MW in 2004. Sharp is believed to have invested JPY 10 billion in capital expansion for its solar module manufacturing capabilities since 2007.

| Sharp Group[a] | | |
|---|---|---|
| Wafer, Cell & Module Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 21,880,000,799 | -1,568,740,913 | -7.17% |
| http://www.sharp.co.uk/icat/bussolar | | |
| Note: [a] Figures are for the Sharp Group as a whole. | | |

Sharp and Enel are cooperating on a joint venture for a thin-film manufacturing plant in Italy at a cost of over USD 1 billion. Production is due to start mid-2010 with an initial annual capacity of 480 MW.[119] Further, Sharp has brought forward plans for a next-generation 1 GW solar thin-film manufacturing plant in Japan and construction is expected to start in late 2009.[120] Sales of solar modules increased by 4 per cent in 2008 and are expected to grow by a further 20 per cent in 2009.[121]

**Wacker Chemie AG**

| Wacker Chemie AG | | |
|---|---|---|
| Feedstock, Ingot & Wafer Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 4,642,700,000 | 681,300,000 | 14.67% |
| http://www.wacker.com/cms/en/home/index.jsp | | |

Wacker Chemie AG is a global company operating within the chemical business. Manufactured products include silicone products, polymer products, chemical materials, polysilicon and monosilicon wafers for both the solar and the semiconductor industry. Recent sales activity includes a long-term contract to sell silicon to Ersol. This amounts to an equivalent of 600 MW between 2010 and 2019.

In the solar PV sector, Wacker Chemie has pursued a strategy of downstream integration, expanding its operations from predominantly silicon feedstock production to ingot and wafer production. In 2007, the firm entered a joint venture with module producer Schott Solar of Germany to produce silicon ingots and wafers through Wacker Schott Solar. In May 2009, the joint venture commissioned a new facility, located in Jena, to produce solar-grade silicon crystals.

The European Investment Bank announced it will provide a EUR 400 million loan to finance Wacker Chemie's new 10,000 tonne polysilicon production facility in Saxony, due to be commissioned in 2011.[122] In February 2009, Wacker Chemie also announced it had purchased 550 acres of land in Tennessee for the construction of a USD 1 billion (EUR 726 million) polysilicon plant.[123]

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119 'Sharp's 1 GW Thin-Film Fab Will Be in Italy,' I-Micronews, 9 December 2008. Available at <www.imicronews.com/news/Sharps-1-GW-thin-film-fab-Italy,2501.html>.
120 Mark Osborne, 'Sharp Shuffles New Thin Film Plant Production Schedule,' PV Tech, 7 January 2009. Available at <www.pv-tech.org/news/_a/sharp_shuffles_new_thin_film_plant_production_schedule/>.
121 Mark Osborne, 'Sharp Seeks 20% Growth in Solar Sales,' PV Tech, 27 April 2009. Available at <www.pv-tech.org/news/_a/sharp_seeks_20_growth_in_solar_sales_in_fy2009/>.
122 Tom Cheyney, 'Wacker Chemie Secures EUR400 Million Loan,' PV Tech, 15 May 2009. Available at <www.pv-tech.org/news/_a/wacker_chemie_secures_400_million_euro_loan_from_eib_for_polysilicon_plant/>.
123 Mark Osborne, 'Wacker Chemie To build US1 Billion Polysilicon Plant in US,' PV Tech, 26 February 2009. Available at <www.pv-tech.org/news/_a/wacker_chemie_to_build_us1_billion_polysilicon_plant_in_u.s/>.

### Sumco Corporation

| Sumco Corporation | | |
|---|---|---|
| Feedstock, Ingot & Wafer Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 3,012,390,762 | 345,810,164 | 11.48% |
| http://www.sumcosi.com/english/ | | |

Sumco Corporation began as a silicon wafer production company with the aim of becoming a world leading wafer producer. The company currently has wafer production capacity of 100 MW. This is expected to grow to 300 MW in 2009 and will eventually reach 1,000 MW. The company is also developing its own silicon production capability with an annual output capacity of 1,010 MW equivalent projected by 2015.

In December 2008, Sumco Techxiv Corp., a subsidiary of Sumco Corporation, announced that it would suspend wafer production at its Omura factory. The suspension came after the company approximately halved its 400-strong workforce from late October 2008.[124] In January, the Corporation announced a revised, and reduced, year-end dividend forecast for the year ending 31 January 2009.

### MEMC

| MEMC | | |
|---|---|---|
| Feedstock, Ingot & Wafer Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 1,474,698,441 | 430,273,610 | 29.18% |
| http://www.memc.com/default-netscape.asp | | |

MEMC, founded in 1959, describes itself as a global leader in the manufacture and sale of wafers to the solar PV industry. The company operates nine manufacturing facilities in Japan, South Korea, Malaysia, Taiwan, Europe and the US. The company is currently involved in a legal battle with Conergy over a 10-year supply contract of solar wafers.

In February 2009, MEMC announced an agreement to cut the contract price of wafers supplied to Gintech Energy, based on the global decline in the price of polysilicon.[125] MEMC is also reviewing its capital spending and polysilicon capacity expansion plans due to lower demand for wafers. The company had previously announced intentions to almost double production from 8,000 metric tonnes per annum in 2008 to 15,000 metric tonnes in 2010.[126] Results from Q1 2009 show a drop in revenue to USD 214 million (EUR 115.4 million), down 50 per cent from the previous quarter.[127]

### Suntech Power Holdings Co. Ltd.

The China-based Suntech Power Holdings Co. Ltd. describes itself as the world's leading solar energy company as measured by production output of crystalline silicon solar modules.

124 'Sumco to Suspend Omura Plant,' Japan Times, 10 December 2008. Available at <search.japantimes.co.jp/cgi-bin/nb20081210a5.html>.

125 Patricia Johnson, 'MEMC Cuts Wafer Price in Contract with Gintech,' PV Tech, 18 February 2009. Available at <www.pv-tech.org/news/_a/memc_cuts_wafer_price_in_contract_with_gintech/>.

126 Mark Osborne, 'MEMC to Review Polysilicon Expansion Plans,' PV Tech, 24 April 2009. Available at <www.pv-tech.org/news/_a/memc_to_review_polysilicon_expansion_plans/>.

127 Mark Osborne, 'MEMC Confirms 50% Fall in Sales,' PV Tech, 10 April 2009. Available at <www.pv-tech.org/news/_a/memc_confirms_50_fall_in_sales_for_first_quarter/>.

Suntech also produces solar cells in-house. The company has regional headquarters in China, Switzerland and the US, with sales offices worldwide. In May 2009, Suntech announced its intention to relocate its European HQ and double its sales team in anticipation of a busy period. The European market represents almost 80 per cent of the company's business.

| **Suntech Power Holdings Co. Ltd.** | | |
|---|---|---|
| Cell & Module Producer & Project Developer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 1,406,295,969 | 64,724,919 | 4.60% |
| http://www.suntech-power.com/ | | |

The company owns and operates projects in the US though Gemini Solar Development Company, which is a joint venture with Renewable Ventures. In May 2009, it was announced that Suntech is searching for a suitable site in the US to locate its manufacturing facility. However, in January 2009, the company shed 4,000 employees, or 30 per cent of its workforce.[128]

### LDK Solar Co. Ltd.

| **LDK Solar Co. Ltd.** | | |
|---|---|---|
| Feedstock, Ingot & Wafer Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 1,208,443,660 | 126,507,796 | 10.47% |
| http://www.ldksolar.com/ | | |

LDK Solar Co. Ltd. designs, develops, manufactures and distributes solar wafers. The company's first commercial shipment was undertaken in April 2006, and annual wafer capacity totalled 1.46 GW by the end of 2008 up by more than 1 GW on 2007.[129] Half of LDK Solar's wafer sales go to its largest customer, Gintech, a Taiwanese solar cell manufacturer. Other companies supplied by LDK Solar include Neo Solar Power Corp, Hyundai Heavy Industries and Moser Baer.

LDK Solar's first plant (1,000 tonne capacity) came online in Q2 2008, while the second plant (15,000 tonne capacity) came online at the end of 2008. In April 2009, LDK Solar formed a joint venture with Q-Cells to promote and supply PV systems for large-scale solar projects in Europe and China. A 40 MW project located in Europe has already been confirmed.[130] Their focus for 2009, however, is on cost reduction rather than further expansion.[131]

### EniPower SPA

In April 2009, EniPower SPA signed an agreement with UniCredit for the renewal of their partnership.[132] EniPower offers companies the supply and installation of PV plants without

128 Fiona Harvey, 'Feeling the Heat,' Financial Times, 3 June 2009. Available at <www.ft.com/cms/s/0/d25b2d04-4fd5-11de-a692-00144feabdc0.html>.
129 Mark Osborne, 'LDK Solar Focuses on Cost Reduction Not Expansion,' PV Tech, 12 March 2009. Available at <www.pv-tech.org/news/_a/ldk_solar_focuses_on_cost_reduction_not_expansion_for_2009/>.
130 Mark Osborne, 'Q Cells and LDK Solar For Joint Venture,' PV Tech, 8 April 2009. Available at <www.pv-tech.org/news/_a/q-cells_and_ldk_solar_form_joint_venture_for_large-scale_solar_energy_plant/>.
131 Mark Osborne, 'LDK Solar Focuses on Cost Reduction Not Expansion,' PV Tech, 12 March 2009. Available at <www.pv-tech.org/news/_a/ldk_solar_focuses_on_cost_reduction_not_expansion_for_2009/>.
132 'Enipower Signs Solar Agreement with UniCredit,' Solar Buzz, 2 April 2009. Available at <www.solarbuzz.com./news/NewsEUCO742.htm>.

requesting payments in advance during the installation. It recently founded an advanced solar research facility at the Massachusetts Institute of Technology (MIT) in the United States.

| **EniPower SPA** | | |
|---|---|---|
| Cell & Module Producer & Project Developer | | |
| Financial Year 2007 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 936,389,000 | 148,547,000 | 15.86% |
| http://www.eni.it/en_IT/home.html | | |

### Sanyo Solar

| **Sanyo Solar** | | |
|---|---|---|
| Ingot, Wafer, Cell & Module Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 571,515,000 | 4,610,000 | 0.81% |
| http://sanyo.com/solar/ | | |

Sanyo Solar, a part of Sanyo Electric Co. Ltd., can trace its solar activities to 1975 when the company first launched amorphous silicon solar cell development. Production of the cells began in 1980. In 2005 the company started mass production of HIT PV modules at its factory in Hungary. The company's first USD 80 million (EUR 57 million) ingot and wafer plant is currently under construction in the US.[133] Capacity of Sanyo Solar's HIT solar cells is due to increase from 340 MW to 600 MW by the end of 2010, with an overall target of 2 GW for HIT cells by 2020.[134] In early 2009, Sanyo Solar and Nippon Oil revealed the formation of a joint company for the production and sale of thin-film solar panels. The new company will be named Sanyo Eneos Solar Co. Ltd. Production will begin in 2010 with an initial capacity of 80 MW.[135]

### Solarfun Power Holdings

| **Solarfun Power Holdings** | | |
|---|---|---|
| Feedstock, Cell & Module Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 526,230,710 | -27,911,889 | -5.30% |
| http://www.solarfun.com.cn/ | | |

Solarfun Power Holdings is a China-based company that manufactures ingots, PV cells and modules. The company also has offices in Spain, Germany, the US and Australia. Capacity in 2008 stood at 360 MW and there are plans to expand to reach 420 MW in 2009. In mid-2008, Solarfun announced an agreement stating that Q-Cells would purchase a minimum of 100 MW of PV modules per annum using PV cells supplied by Q-Cells from 2009 through 2011.

Solarfun does not produce its own wafers, but acquires them by means of short-term contracts with suppliers, such as the Wacker Chemie joint venture. In 2008 Solarfun acquired a 52 per cent stake in Yangguang Solar, a producer of silicon and ingots. The

133 Tom Cheyney, 'Work in Progress,' PV Tech, 14 May 2009. Available at <www.pv-tech.org/chip_shots/_a/work_in_progress_exclusive_photos_of_sanyo_solars_new_oregon_ingotwafer_pla/>.
134 'Sanyo to Raise Cell Capacity to 600 MW,' Solar Buzz, 17 February 2009. Available at <www.solarbuzz.com./news/NewsASMA226.htm>.
135 'Sanyo and Nippon Oil Establish Thin-Film Joint Venture,' Solar Buzz, 23 January 2009. Available at <www.solarbuzz.com/news/NewsASCO396.htm>.

company is pursuing further vertical integration to the ingot and wafer level, and expects to have 300 MW of wafer capacity by mid-year 2009.[136] Net revenue in Q1 2009 stood at RMB 684.2 million which equates to a 43 per cent year-on-year decrease. PV module shipments totalled 35.7 MW, a 25 per cent decrease from Q4 2008 of 47.6 MW.

**Canadian Solar**

| **Canadian Solar** | | |
|---|---|---|
| Ingot, Wafer, Cell & Module Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 521,476,905 | 0 | 0.00% |
| http://www.canadian-solar.com/ | | |

Canadian Solar, founded in 2001, describes itself as a vertically-integrated manufacturer of ingots, wafers, cells, solar modules and custom-designed solar power applications. Recent activity includes a contract to sell 5 MW of modules to Topinfrasolar, a South Korean systems integrator.[137] The company has also signed a sales contract to supply a further 5 MW of modules to Helio Micro Utility.[138] In April 2009, the company was selected by China's Ministry of Agriculture and the Sichuan provincial government to supply PV systems to 80,000 rural households in Sichuan, China.[139]

There are currently plans to increase total solar cell capacity from 270 MW to 420 MW by Q3 2009. In-house ingot production will also increase 200 MW, up from approximately 150 MW. Module production capacity is expected to remain at around 620 MW throughout 2009.

Results from Q1 2009 show net revenues of USD 49.5 million (EUR 35 million), down from USD 171.2 million (EUR 121.3 million) from Q1 2008. This represents shipments of 18 MW.

**ReneSola**

| **ReneSola** | | |
|---|---|---|
| Feedstock, Ingot, Wafer & Cell Producer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 492,791,998 | -44,130,627 | -8.96% |
| http://www.renesola.com/ | | |

ReneSola is a China-based solar company that in 2008 was recognised as the fourth fastest growing Chinese technology company by Deloitte. The company currently produces both silicon ingots and wafers but is pursuing vertical integration within the PV value chain.

In January 2009, the company announced that its wholly owned subsidiary, Suchuan ReneSola Material Co. Ltd., had secured a loan to construct a polysilicon production facility.[140] Net

136 Andrew Siegfried, 'The Future is Bright for Solarfun,' China Perspective, 23 September 2008. Available at <www.thechinaperspective.com/articles/thefutureisbrightforsolarfun4709/index.html>.
137 Mark Osborne, 'Korean Systems Integrator Secures 5 MW Module Deal with Canadian Solar,' PV Tech, 5 May 2009. Available at <www.pv-tech.org/news/_a/korean_systems_integrator_secures_5mw_module_deal_with_canadian_solar/>.
138 Tom Cheyney, 'Canadian Solar, Helios Micro Sign 5-MW Module Supply Deal,' PV Tech, 10 April 2009. Available at <www.pv-tech.org/news/_a/canadian_solar_helios_micro_utility_sign_5-mw_module_supply_deal/>.
139 Tom Cheyney, ' Canadian Solar to Supply PV Systems to 80,000 Rural Households,' PV Tech, 6 April 2009. Available at <www.pv-tech.org/news/_a/canadian_solar_to_supply_pv_systems_to_80000_rural_households_in_sichuan_ch/>.
140 Patricia Johnson, 'Renesola Secures RMB800 Million Loan,' PV Tech, 28 January 2009. Available at <www.pv-tech.org/news/_a/renesola_secures_rmb800_loan_for_sichuan_polysilicon_production_facility/>.

revenue in Q1 2009 stood at USD 106.9 million (EUR 75.8 million), a 13 percent year-on-year decrease and a further decrease of 32.6 per cent from Q4 2008.

### Centrosolar Group AG

| Centrosolar Group AG | | |
|---|---|---|
| Cell & Module Producer & Project Developer | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 354,145,000 | 1,2005,000 12,005,000 | 3.39% |
| http://www.centrosolar.de/ | | |

Centrosolar Group AG is a German-based PV business focussing on roof-mounted 'plug-and-play' systems for the European market. The group owns the subsidiaries Biohausm Solara and Solarstocc PV. The company uses modules produced in-house as well as by third parties and is not currently locked into long-term supply agreements. It can therefore take advantage of lower module prices, which, it claims, have declined as much as 20 per cent in the first five months of 2009. Increased business in the French, Swiss and US markets in Q1 2009 helped to account for revenues of EUR 61.7 million, which is down only 7 per cent from Q1 2008.

Centrosolar is holding talks to replace Qimonda Solar GmbH as a joint venture partner for the Itatrion solar cell plant.[141] In February 2009, the Dutch Econcern group sold its 30 per cent stake in the Centrosolar subsidiary company Ubbink Solar Modules (USM). The shares were purchased by Centrosolar, which now owns USM in its entirety. However, USM is to close down its module production plant following the loss of Ecostream Switzerland GmbH as the principal customer for USM modules.[142] Additionally, a decrease in demand during Q1 2009 forced Centrosolar to write-down its remaining 2008 PV module and materials inventory, costing the company EUR 4 million.

### Table 3.13: Balance of partially integrated companies sampled

| Company Name | Value Chain Segment | Financial Year | Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
|---|---|---|---|---|---|
| PV Crystalox Solar plc | Feedstock, Ingot & Wafer Producer | 2008 | 274,095,000 | 147,223,000 | 52.10% |
| Sunways AG | Cell & Module Producer & Project Developer | 2008 | 262,341,000 | -2,681,000 | -1.02% |
| Isofoton | Cell & Module Producer & Project Developer | 2007 | 259,950,000 | -21,174,000 | (-8.15%) |
| Sovello A.G. | Wafer, Cell & Module Producer | 2008 | 219,000,000 | N/A | N/A |
| Solar Fabrik | Wafer, Cell & Module Producer | 2007 | 217,279,000 | -33,538,000 | -15.44% |
| Scheuten Solar | Cell & Module Producer & Project Developer | 2007 | 180,512,000 | 7,985,000 | 4.42% |
| Evergreen Solar Inc. | Wafer, Cell & Module Producer | 2008 | 82,347,014 | -68,674,610 | -83.40% |
| Topsil Semiconductor | Feedstock, Ingot & Wafer Producer | 2008 | 38,858,424 | 8,614,050 | 22.17% |
| Dyesol UK Limited | Cell & Module Producer & Project Developer | 2008 | 1,394,128 | 110,081 | 7.90% |
| Podolsky Chemical | Ingot, Wafer & Cell Producer | - | N/A | N/A | N/A |

Note: N/A: not available

141 Mark Osborne, 'Centresolar Makes 4 Million Solar Modules Write-off,' PV Tech, 13 May 2009. Available at <www.pv-tech.org/news/_a/centrosolar_makes_4_million_solar_module_write-off/>.

142 'Centrosolar Shuts Down Module Manufacturing Facility,' Solar Buzz, 4 June 2009. Available at <www.solarbuzz.com/News/NewsEUMA301.htm>.

### *3.5.2.2.7 Strategic Approved 4 - Full Value Chain Integration*

Complete integration is, by definition, not practically possible as no firm can control the supply of every required manufacturing input and drive the ultimate demand for its outputs.[143] For the purposes of this report, the term "full integration" will be used to describe those firms that have managed to ***integrate through at least five of the sector's six key value chain stages***. Of the 108 companies sampled, 15 were considered fully integrated. BP Solar is included although its future as an integrated solar PV firm is uncertain.

**Barriers to Entry**

Given the relatively high barriers to entry offered by capital-intensive manufacturing processes and the need for specialist R&D expertise at all stages of the solar PV value chain, full integration requires considerable investment in both capital and human resources over a prolonged period.

Among the many benefits of full integration is the ability to price outputs at lower levels owing to both economies of scale and access to cost savings and lower profit margins at multiple stages in the value chain. For a potential new entrant or company wishing to integrate into a new segment along the value chain, price reduction increases the barriers to entry still further as, assuming stable demand, a lower market price for downstream products tends to lead to a longer capital payback period for manufacturers.

As the solar PV sector continues to grow beyond the financial crisis it will be interesting to observe whether any large diversified conglomerate companies enter the sector at multiple stages in the value chain. Samsung, as a competitor to Kyocera, Mitsubishi and other similar firms, would potentially have the capital reserve and technical expertise to do so. There has also been some concern amongst incumbent companies in the sector that large semiconductor manufacturers may leverage their existing expertise and access to high-quality raw materials to enter the solar PV market.[144]

**Profitability**

There are a number of fully integrated companies now operating in the solar PV sector. Some companies, such as Q-Cells and SunPower, operate exclusively in the solar industry, while others, such as Mitsubishi Electric and Kyocera, are subsidiary members of significantly large diversified conglomerate companies.

Interestingly, among the sample of fully integrated companies, all were profitable according to their most recently published financial statements. This is in stark contrast to the partially integrated companies sampled, of which approximately 40 per cent broke even or reported an operating loss. This difference suggests that, whilst difficult to achieve given the barriers to entry provided by high capital costs and requisite personnel expertise in the sector, the benefits of adopting a strategy of full integration are considerable. SunPower claims that it achieves higher gross margins on projects that utilise SunPower solar modules than projects that use third-party suppliers. It is thus trying to increase the use of SunPower modules from 60 per cent to 80 per cent of the total number of modules used in its solar systems.

The effects of the financial crisis and recession will no doubt weaken the 2008/2009 results for all of these fully integrated companies. As evidenced by BP's strategic decision to gradually

143 12 Manage, Vertical Integration. Available at <www.12manage.com/methods_vertical_integration.html>.
144 Trina Solar, Form 20-F. Available at <ccbn.10kwizard.com/cgi/convert/pdf/TrinaSolarLtd20F.pdf?ipage=6292978&num=-2&pdf=1&xml=1&cik=1382158&odef=8&rid=12&quest=1&xbrl=0&dn=2&dn=3>.

reduce its investment in the solar PV sector, some diversified companies may choose to focus on other, more profitable, business interests.[145]

### 3.5.2.2.8. *Fully-Integrated Company Profiles*

**Mitsubishi Electric Corporation**

| **Mitsubishi Electric Corporation** | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 28,165,231,170 | 829,391,097 | 2.94% |
| http://global.mitsubishielectric.com/ | | |

Mitsubishi Electric Corporation is a global manufacturer of electric goods and a major producer and developer of solar PV equipment. The company has over 35 years experience in the PV industry, with R&D of PV technology beginning in 1974. In February 2009, Mitsubishi Electric announced that it has developed the most efficient multicrystalline silicon PV cell in the world with a conversion efficiency rate of 18.9 per cent.[146]

The company has polycrystalline ingots produced through their subsidiary, Jemco Inc., which in 2008 spent JPY 1.4 billion (EUR 10.7 million) to build a new plant to triple output capacity to 290 tonnes.[147] In August 2008, the company announced that it would construct a new solar cell plant at its Nakatsugawa Works Iida Factory in Japan. This forms part of the company's plan to raise annual cell production capacity to 600 MW by 2012.[148]

**Norsk Hydro**

| **Norsk Hydro** | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 10,018,761,938 | 134,950,326 | 1.35% |
| http://www.hydro.com/en/ | | |

Through a series of investments in solar companies, Norsk Hydro expanded its interest in the solar power sector considerably in the last four years. Currently Norsk Hydro holds a stake in a number of companies: Convexa, a solar PV technology company; Norson, a producer of crystalline silicon wafers with production facilities in Norway and Finland; Ascent Solar, a producer of solar modules based in Colorado; and Hycore, a joint venture with Umicore focussing on the production of solar grade silicon.

145 Ed Crooks, 'Sun Sets on BP Solar's Hopes,' Financial Times, 13 May 2009. Available at <www.ft.com/cms/s/0/d7b2a18e-3ff3-11de-9ced-00144feabdc0.html>.
146 Ed Crooks, 'Sun Sets on BP Solar's Hopes,' Financial Times, 13 May 2009. Available at <www.ft.com/cms/s/0/d7b2a18e-3ff3-11de-9ced-00144feabdc0.html>.
147 Mark Osborne, 'New Product: Mitsubishi Electric Boosts Multicrystalline Cell Efficiency,' PV Tech, 19 February 2009. Available at <www.pv-tech.org/product_briefings/_a/new_product_mitsubishi_electric_boosts_multicrystalline_cell_efficiency_to_/>.
148 'Mitsubishi Launches Solar Cell Silicon Sales,' Antara News, 17 October 2008. Available at <www.antara.co.id/en/arc/2008/10/17/mitsubishi-materials-launches-solar-cell-silicon-sales/>.

**Q-Cells**

| Q-Cells | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 1,251,300,000 | 205,100,000 | 16.39% |
| http://www.q-cells.com/en/index.html | | |

Founded in 1999 and based in Germany, Q-Cells have grown to become the world's largest solar cell manufacturer. In 2008 the company produced 574 MW of solar cells, up from 398 MW in 2007.

Q-Cells previously held a 17.2 per cent share stake in Renewable Energy Company (REC), which has since been sold. The sale enabled Q-Cells to raise EUR 530 million.[149] The company has also formed a joint venture with LDK Solar which focuses on PV systems and market development across Europe and China.[150] In May 2009, Q-Cells ceased investments in the thin-film solar start-up CSG Solar AG. This forms part of the company's cost management program.[151] Further, Q-Cells was forced to make its third successive projection for 2009 revenues. New projections of EUR 1.3-1.6 billion replace previous expectations of EUR 1.7-2.1 billion.[152] Similarly, productions targets for 2009 have been revised to between 600-800 MW which is down from the previous production target of 800 MW-1 GW.

**SunPower Corporation**

| SunPower Corporation | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 1,055,397,911 | 123,909,238 | 11.74% |
| http://us.sunpowercorp.com/ | | |

SunPower Corporation designs, manufactures and delivers high-efficiency solar power technology globally, with a history dating back more than 20 years. The company has major supply agreements in place with the Italian PV integrator Ecoware S.p.A.[153] and the German integrator City Solar Kraftwerke AG.[154] These agreements amount to 230 MW of modules over four years.

SunPower Corporation has a contract in place for an annual supply of 550,000 MWh of renewable energy to the US energy utility, Pacific Gas and Electric Company. This supply will come from SunPower Corporation's planned 250 MW solar plant, due to be located in California.[155] Exelon and

149 Mark Osborne, 'Mitsubishi Electric Raises MW Capacity Target,' PV Tech, 27 August 2008. Available at <www.pv-tech.org/news/_a/mitsubishi_electric_raises_mw_capacity_target_constructs_new_solar_cell_pla/>

150 Mark Osborne, 'Q Cells to Sell Major Stake in REC to Reduce Debt,' PV Tech, 6 May 2009. Available at <www.pv-tech.org/news/_a/q-cells_to_sell_major_stake_in_rec_to_reduce_debt/>.

151 'Q Cells and LDK Solar Form Joint Venture,' Solar Buzz, 8 April 2009. Available at <www.solarbuzz.com./news/NewsEUCO744.htm>

152 Mark Osborne, ' Q Cells Revises Revenue Capital Spending and Production Targets,' PV Tech, 12 May 2009. Available at <www.pv-tech.org/news/_a/q-cells_revises_revenue_capital_spending_and_production_targets/>

153 Mark Osborne, 'Sunpower Signs 130 MW deal with Italian PV Integrator, ' PV Tech, 10 November 2008. Available at <www.pv-tech.org/news/_a/sunpower_signs_130mw_deal_with_italian_pv_integrator/>.

154 Mark Osborne, 'Sunpower Secures 3-year 100 MW Supply Deal with German power Plant Integrator,' PV Tech, 1 December 2008. Available at <www.pv-tech.org/news/_a/sunpower_secures_3-year_100mw_supply_deal_with_german_power_plant_integrato/>.

155 Mark Osborne, 'PGE Power Purchase Agreements for 800 MW with Optisolar and Sunpower,' PV Tech, 1 December 2008. Available at <www.pv-tech.org/news/_a/pge_power_purchase_agreements_for_800mw_with_optisolar_and_sunpower/>.

SunPower Corporation are cooperating to build a USD 60 million (EUR 42.5 million) 10 MW solar power plant in Chicago. This will be reportedly the largest solar development plan in an urban setting in the US.[156]

Results from Q1 2009 show that revenue is down 53 per cent from Q4 2008 to USD 214 million (EUR 155.4 million). Consequently, capital expenditure and expansion plans in the Philippines have been put on hold.[157] The company did have plans to build a 1 GW cell manufacturing facility in Malaysia.[158]

### REC Group

| REC Group | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 925,777,321 | 494,930,886 | 53.46% |
| http://www.recgroup.com/ | | |

REC Group operates in three divisions: REC Silicon, REC Wafer and REC Solar. REC Silicon is the world's largest dedicated producer of silicon materials made solely for the PV industry. REC Solar is responsible for the production of solar cells and modules and operates a small systems installation company in South Africa.

In June 2008, the company entered a USD 600 million (EUR 425 million) contract to supply multicrystalline wafers to Gintech between 2009 and 2015. REC has a similar contract with USD 300 million (EUR 212.6 million) in place with Suniva Inc. Between 2009 and 2013, as well as a USD 400 million (EUR 283.4 million) wafer sales agreement with China Sunergy Co. Ltd. up until 2015. In September 2008, REC finalised a contract to supply Neo Solar Power with USD 400 million (EUR 283.4 million) in multicrystalline wafers between 2009 and 2015.

In early 2009, the company announced that it would be cutting module production levels by 50 per cent in Q2. However, REC anticipates levels returning to normal in the second half of the year due to existing contracts. The company did, however, experience problems at its polysilicon facility in Moses Lake, which forced it to shut down. Consequently, polysilicon production will be down by 10-15 per cent to 9,000 metric tonnes in 2009.[159]

### SolarWorld AG

| SolarWorld AG | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 900,311,000 | 260,800,000 | 28.97% |
| http://www.solarworld.de/?L=1 | | |

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156 Tom Cheyney, 'Exelon, Sunpower Join Forces to Build a 10 MW Solar Power Plant in Chicago,' PV Tech, 22 April 2009. Available at <www.pv-tech.org/news/_a/exelon_sunpower_join_forces_to_build_10-mw_solar_power_plant_in_chicago/>.

157 Mark Osborne, 'Sunpower Cuts Production Expansion,' PV Tech, 27 April 2009. Available at <www.pv-tech.org/news/_a/sunpower_cuts_production_expansion_plans_as_module_inventory_rises_and_sale/>.

158 Mark Osborne, 'Sunpower to Build 1 GW Scale Fab in Malaysia,' PV Tech, 19 May 2008. Available at <www.pv-tech.org/news/_a/sunpower_to_build_1gw_scale_fab_in_malaysia/>.

159 Mark Osborne, 'REC Lower Polysilicon Forecast Cuts Solar Module Production,' 29 April 2009. Available at <www.pv-tech.org/news/_a/rec_lowers_polysilicon_production_forecast_cuts_solar_module_production/>.

SolarWorld AG is a German-based solar company founded in 1998. The company operates subsidiaries in Germany, Spain, Asia, Africa and the US and is involved in each stage of the solar value chain. The company was reported to be Germany's fastest growing company in 2008.

SolarWorld has been producing polysilicon since 2002 through its joint venture with the chemical company Degussa. SolarWorld has had a further silicon production joint venture with Scheuten Solarholding B.V. since 2006. Wafers are produced in Germany and the US through the subsidiaries Deutsche Solar AG and Solar Industries America, which are also responsible for the production of cells. Solar modules are produced through the subsidiaries Solar Factor GmbH, Gällivare Photovoltaic AB (GPV) in Sweden and via SolarWorld Industries America.

SolarWorld is the world's second-largest wafer producer and uses only 50 per cent of its wafer production, selling the remaining 50 per cent to other manufacturers. Solarworld owns a 19 per cent stake in Blue Chip Energy of Austria, which focuses exclusively on the manufacturing of solar cells.

The company reported that Q1 2009 sales increased by 5.2 per cent to EUR 176.3 million compared to Q1 2008. However, this is a decrease from Q4 2008.[160] There are plans to increase cell manufacturing to 1 GW by the end of 2010 following a EUR 250 million investment in a new plant located in Freiberg, Germany.[161]

**Trina Solar Ltd.**

| **Trina Solar Ltd.** | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 611,871,765 | 48,543,689 | 7.93% |
| http://www.trinasolar.com/ | | |

Founded in 1997, based in China, Trina Solar Ltd. is a manufacturer of PV modules. The company has also developed vertically to produce ingots, wafer and cells which are all produced at its facilities in Changzhou, China. Module production capacity increased from 150 MW at the end of 2007, to 350 MW by the end of 2008. As of May 2009, the figure stood at 400 MW.

Trina Solar had a plan to invest USD 1 billion (EUR 708.6 million) to establish its own silicon production facility with an annual capacity of 10,000 tonnes. However, in April 2008, the firm decided not to go ahead with this investment. Silicon will continue to be procured through long-term contract arrangements with existing suppliers. Trina Solar purchased silicon from GSL Silicon Technology (enough to produce approximately 4,825 MW of modules over eight years). Contracts are in place for Qingdao DTK to supply Trina Solar with enough polysilicon to produce approximately 650 MW of modules over six years. Agreements are also in place with Silfab and Jupiter Corporation.

Results from Q1 2009 show module shipments at 48.8 MW, 15 per cent lower than expected though still an increase of 65 per cent from Q1 2008. Total net revenues were USD 132 million (EUR 93.5 million), which is an increase of 9.5 per cent from Q1 2008, although it is 39 per cent

160 Mark Osborne, 'Solarworld Bucks Trend, Increases Sales in Q1,' PV Tech, 15 May 2009. Available at <www.pv-tech.org/news/_a/solarworld_bucks_trend_increases_sales_in_q1/>.

161 Mark Osborne, 'Solarworld Targets 1 GW Cell Production in Freiberg,' PV Tec, 18 May 2009. Available at <www.pv-tech.org/news/_a/solarworld_targets_1gw_cell_production_in_freiberg/>.

less than Q4 2008. This downturn was blamed on unusually harsh weather in Europe and the slowdown in global economic activity.

### Motech Power

| Motech Power | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 509,556,270 | 61,657,668 | 12.10% |
| http://www.motech.com.tw/ | | |

Motech Power, founded in 2002, describes itself as Taiwan's largest installer of PV power systems, having installed over 50 solar power systems which produce more than 200 kW. Originally a cell manufacturer, the firm has backwards integrated to produce ingots and wafers. Although Motech Power will remain dependent upon wafer suppliers, it produced 12 MW of wafers internally in 2008 and this is projected to increase to 100 MW in 2009 and 200 MW in 2010. In May 2009 Motech Power announced a further investment of USD 25 million (EUR 17.7 million) in AE Polysilicon Corporation, raising its stake in the company to 50.2 per cent.

Motech Power planned to expand its solar cell production capacity to 450 MW by the end of 2008 and 800 MW by the end of 2009. Actual production was 176 MW in 2007 and is projected to grow to 294 MW in 2009 and 750 MW in 2010.

The company has a strategic partnership in place with Solar Semiconductor for the supply of 120 MW of cells.[162] Unconsolidated net revenues from Q1 2009 are reported at TWD 4,021 million (EUR 87.6 million) which is down 81 per cent from Q1 2008, and 90 per cent from Q4 2008.

### Schott Solar

| Schott Solar | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 482,000,000 | 52,000,000 | 10.79% |
| http://www.us.schott.com/photovoltaic/english | | |

Schott Solar, a wholly owned subsidiary of Schott AG, is a manufacturer of solar PV modules, using crystalline silicon and thin film, as well as a producer of CSP systems. Through its partnership with Wacker, known as Wacker Schott, Schott now has access to raw silicon, ingot and wafer production. Schott will use some wafers for its own cell production, however, the majority of wafers will be sold to other cell manufacturers. The aim is for the company to become a top-five wafer producer. In May 2009, the joint venture commissioned a new silicon crystallisation factory in Jena. Capacity is expected to total 275 MW by the end of 2009.[163]

In 2008, Schott Solar began cooperating with Ersol Thin Film GmbH in order to develop thin- film cells. The company also founded Schott Solar Thin Film GmbH in Jena, Germany.

162 Sile McMahon, 'Solar Semiconductor Secures Cell Supply from Motech,' PV Tech, 7 May 2008. Available at <www.pv-tech.org/news/_a/solar_semiconductor_secures_cell_supply_from_motech/>.
163 Tom Cheyney, 'Wacker Schott Solar Commissions Silicon Crystallization Factory,' PV Tech, 28 May 2009. Available at <www.pv-tech.org/news/_a/wacker_schott_solar_commissions_silicon_crystallization_factory_begins_tool/>.

In May 2009, the company opened a new USD 100 million (EUR 70.86 million) PV module facility in Albuquerque, US. Initial output is expected to be 85 MW.

**Yingli Green Energy Holding Co. Ltd.**

| Yingli Green Energy Holding Co. Ltd. | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 437,464,760 | 73,232,930 | 16.74% |
| http://www.yinglisolar.com | | |

Yingli Green Energy Holding Co. Ltd. describes itself as one of the largest manufacturers of PV products in China, as measured by annual production capacity. The company covers much of the PV value chain, and production capacity in September 2008 stood at 400 MW of polysilicon ingots and wafers, 400 MW of PV cells and 400 MW of PV modules.

Yingli Green has a long-term polysilicon supply agreement with Wacker Chemie AG from 2010 to 2017 to produce approximately 380 MW of PV modules. Yingli Green recently announced a three-year polycrystalline PV module supply agreement with AES whereby Yingli Green will be AES's exclusive supplier.[164]

The company recently announced cooperation with the Dutch Energy Research Centre (ECN), and process tool maker Amtech Systems, to research and develop the next generation of high-efficiency silicon PV cells.[165] Total net revenues in Q1 2009 stood at RMB 999.9 million (EUR 102.8 million), which represents a decrease of 43.2 per cent from Q4 2008 and 37.3 per cent from Q1 2008. This was attributed to difficult global conditions, harsh weather in Germany, and changes to the feed-in tariff policy in Spain.

**Kyocera Solar**

| Kyocera Solar | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 361,000,000 | 32,260,000 | 8.94% |
| http://www.kyocerasolar.com/ | | |

Kyocera Solar describes itself as one of the world's largest vertically integrated producers and suppliers of solar energy products.

In March 2009, Kyocera Solar's second Mexican PV module manufacturing plant opened. The annual output capacity is 150 MW.[166] Other module manufacturing facilities are located in the Czech Republic, China and Japan. By 2012, the four sites will have a combined annual capacity of 650 MW. There are also plans for a further Chinese PV module plant which will boost existing site capacity from 60 MW to 240 MW.[167] In November 2008, the company announced

164 Mark Osborne, 'Is Yingli Green Closing the Cost per Watt Gap with First Solar?' PV Tech, 18 May 2009. Available at <www.pv-tech.org/editors_blog/_a/is_yingli_green_closing_the_cost_per_watt_gap_with_first_solar/>.
165 Tom Cheyney, 'Yingli Green, ECN, Amtech Join Forces on Next Generation Solar Cell R&D Effort,' PV Tech, 1 June 2009. Available at <www.pv-tech.org/news/_a/yingli_green_ecn_amtech_join_forces_on_next-generation_solar-cell_rd_effort/>.
166 Tom Cheyney, 'Kyocera Solar Opens New PV Module Plant in Tijuana, Mexico,' PV Tech, 8 March 2009. Available at <www.pv-tech.org/news/_a/kyocera_solar_opens_new_pv_module_plant_in_tijuana_mexico/>.
167 Tom Cheyney, 'Kyocera to Build New Chinese Solar PV Module PV Plant will Quadruple Capacity,' PV Tech, 20 February 2009. Available at <www.pv-tech.org/news/_a/kyocera_to_build_new_chinese_solar_pv_module_plant_will_quadruple_capacity_/>.

plans to build a new solar cell manufacturing facility in Japan. The new facility will help to increase Kyocera Solar's global output of cells to 650 MW per year by 2012.

**Ersol Solar Energy AG**

| Ersol Solar Energy AG | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 317,894,000 | 65,099,000 | 20.48% |
| http://www.ersol.de/en/home | | |

Founded in 1997, Ersol Solar Energy AG is a subsidiary of Robert Bosch, and is highly vertically integrated in the solar PV value chain. The company wholly owns the following subsidiaries: Ersol Silicon, Ersol Wafers, Ersol Solar Cells and Ersol Modules. The company also holds a 35 per cent interest in the joint venture Shanghai Electric Solar Energy Co. Ltd. and a 50.001 per cent stake in Ersol Thin Film GmbH.

In May 2009, the company lowered its revenue forecasts for both 2008 and 2009. Consolidated revenue for Q1 in 2009 stood at EUR 32.4 million, down from EUR 52.4 million in Q4 2008.[168]

**Photowatt Technologies**

| Photowatt Technologies | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 146,084,878 | 4,633,716 | 3.17% |
| http://www.photowatt.com/ | | |

Photowatt International was founded in 1979, primarily as a research organisation to explore PV technology. After its acquisition by ATS Automatic Tooling Systems in 1997, the company rapidly expanded capacity from 3 MW in 1996 to 60 MW in 2007, and plans to exceed 100 MW in future years.

Along with SolarWorld, Sharp, Sanyo, Solara and Scheuten Solar, Photowatt are a module supplier to the French PV systems installer Aehlios.[169] The company also has a 67.5 MW three-year module supply agreement in place with EDF Energies Nouvelles, with the option for an additional 37.5 MW. This contract is due to run until 2010.[170]

In April 2009, Photowatt announced it would be shutting down production for three weeks due to decreased demand for PV modules and systems. The company reported that the time spent shut down would be used to implement process improvements.[171]

168 Mark Osborne, 'Ersol Solar Energy AG Revises Sales Forecast through 2010,' PV Tech, 15 May 2009. Available at <www.pv-tech.org/news/_a/ersol_solar_energy_ag_revises_sales_forecast_through_2010/>.

169 Tom Cheyney, 'Scheuten Solar Inks Deal to Supply PV Modules to Aehlios,' PV Tech, 25 February 2009. Available at <www.pv-tech.org/news/_a/scheuten_solar_inks_deal_to_supply_pv_modules_to_aehlios/>.

170 'EDF Energies Nouvelles Signs 3rd PV Supply Contract,' Cleantech, 16 October 2007. Available at <cleantech.com/news/1943/edf-energies-nouvelles-signs-third-pv-supply-contract>.

171 'French Solar Manufacturer Photowatt to Shut Down Production for 3 Weeks,' I-Micron News, 29 April 2009. Available at <www.imicronews.com/news/French-solar-manufacturer-Photowatt-shut-production-three-w,3049.html>.

**CNPV Dongying Photovoltaic Power Company Ltd.**

| **CNPV Dongying Photovoltaic Power Company Ltd.** | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| 17,703,612 | 930,118 | 5.25% |
| http://www.cnpv-power.com/ | | |

Founded in 2006, CNPV describes itself as a leading multi-product solar company that produces ingots, wafers, cells and solar modules for residential, commercial and industrial sites. Capacity reached 160 MW by the end of 2008, and is planned to increase to 200 MW by the end of 2009.

**BP Solar**

| **BP Solar** | | |
|---|---|---|
| Fully Integrated | | |
| Financial Year 2008 | | |
| Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
| N/A | N/A | N/A |
| http://www.bp.com/genericcountryjump.do?categoryId=9070&contentId=7038143 | | |

BP Solar, a subsidiary of BP plc, describes itself as one of the world's largest solar companies, with a history dating back more than 30 years and installations in over 160 countries. The company occupies the entire solar value chain.

In April 2009, BP Solar announced that its workforce would be reduced by 28 per cent to 1,580.[172] This includes the closure of two cell and solar module assembly plants near Madrid, as well as a phasing out of a module assembly plant in the US. These closures form part of a plan to cut costs by 25 per cent by the end of 2010.[173] BP plc reduced investment in its alternative energies from USD 1.4 billion (EUR 1.01 billion) in 2008 to USD 1 billion (EUR 726.2 million) in 2009.[174] In addition, Silex Systems, a high technology firm, has acquired the manufacturing assets and equipment of a BP Solar facility located in Sidney.[175] Recent activity includes a contract to supply 66 MW of PV modules to RGE Energy, and collaboration with SolarEdge Technologies Ltd. to investigate commercialisation of a PV module-integrated power harvesting system embedded into BP Solar modules.[176]

### 3.5.3. The Effects of the Financial Crisis, Global Recession and Plunge in Commodity Prices

In the aftermath of the financial crisis and recession it is likely that the European solar PV sector will continue to experience lower levels of demand causing excess supply capacity which in turn will put pressure on producers to lower their prices and result in

172 Terry Macalister, 'BP Axes 620 Jobs from Solar Business,' Guardian, 1 April 2009. Available at <www.guardian.co.uk/environment/2009/apr/01/bp-solar>.
173 Tom Cheyney, 'Headline Blues: BP Solar Puts Costs Reduction Spin on job Cuts,' PV Tech, 1 April 2009. Available at <www.pv-tech.org/chip_shots/_a/headline_blues_bp_solar_puts_cost_reduction_spin_on_job_cuts_while_third-pa/>.
174 Ed Crooks, 'Sun Sets on BP Solar's Hopes,' Financial Times, 13 May 2009. Available at <www.ft.com/cms/s/0/d7b2a18e-3ff3-11de-9ced-00144feabdc0.html>.
175 Tom Cheyney, 'Silex Systems to Buy, Recommission Shuttered BP Solar Facility in Sydney,' PV Tech, 27 May 2009. Available at <www.pv-tech.org/news/_a/silex_systems_to_buy_recommission_shuttered_bp_solar_facility_in_sydney/>.
176 Merav Ankori, 'BP Solar to Use SolarEdge Technology,' Globes, 1 June 2009. Available at <www.globes.co.il/serveen/globes/docview.asp?did=1000454742&fid=942>.

tighter margins. As can already be seen from early results in 2009, many companies are being forced to re-state their revenue projections and profit forecasts. The effects on the entire industry are likely to be severe, and will have a particularly interesting effect on the competitive landscape of the solar PV sector.

It is widely accepted that the financial crisis will lead to consolidation through horizontal integration in the solar PV sector;[177] however, beyond this superficial view, the overall effect of the financial crisis and a weaker global economy on the vertical integration strategies adopted by solar PV firms is less clear.

As with other sectors, it is likely that solar PV firms with strong parent companies as well as healthy, integrated firms with the ability to reduce costs and capture profit margins at each stage of the solar PV value chain, will be more stable than those with weak capital reserves, high levels of debt or weak control over multiple segments of the value chain. For those healthy firms, the financial crisis presents a strategic opportunity to improve their competitive position. Healthy incumbent specialist companies may try and consolidate their market positions and merge with or acquire new market entrants or struggling competitors. Other specialist companies and specialist integrators may view the financial crisis as an opportunity to integrate vertically through the acquisition of struggling specialists in upstream or downstream segments of the value chain.

For specialists with less access to profit margins at multiple stages of the value chain, both consolidation and integration are likely to be restricted by the reduction in available investment for merger and acquisition deals. This will be due to external factors from financial markets and internal factors such as pressure to maintain healthy liquidity levels.

Full, partial and specialist integrators are faced with conflicting pressures as a result of the global recession. On the one hand, an expanded vertical or horizontal integration strategy may appear attractive as struggling acquisition targets are likely to be available at relatively low purchase prices throughout the value chain. Conversely, the pressure to maintain profitability levels despite shrinking margins at multiple stages of the value chain may cause integrated firms to return to their core competencies and divest in non-core business units.

177 Fiona Harvey, 'Feeling the Heat,' Financial Times, 3 June 2009. Available at <www.ft.com/cms/s/0/d25b2d04-4fd5-11de-a692-00144feabdc0.html>.

# Chapter 4: Conclusion

The technology for using solar energy as a source for power generation has never been competitive with fossil-fuel power plants. Although solar energy has been used for decades, solar power technology has yet to reach a level of conversion efficiency or a total cost low enough to make it a commercially viable and attractive power-generating technology for the mass market.

To promote the development of the sector, governments have, over the last five to 10 years, introduced a series of incentives to increase the rate of development of solar technology. Without government incentives, the required investment to support technological development would arguably never be attracted to the solar power sector. The market growth and technological improvements between 2004 and 2008 can largely be attributed to the successful implementation of attractive solar power incentives in Europe.

Largely as a result of the attractiveness of solar PV incentives of a few governments in Europe, a flood of new investment has poured into the solar PV sector since 2004. Investment targets were identified by various types of investors in all renewable energy sectors, and from 2006 to 2008 the solar power industry experienced an extraordinary increase in investment, receiving USD 31 billion (EUR 22 million) in 2008 at a higher year-on-year growth rate than any other major renewable energy technology.

The financial crisis hit Europe as hard as any other region, and as a result available finance for solar power development has contracted dramatically. Availability of credit has shrunk and the time required to secure project finance has increased from approximately four weeks in 2007 to eight to 10 weeks in early 2009.[178] The full effects of this fall in available finance are being felt throughout the sector, with many of the largest companies adjusting down their forecasts and financial outlooks.

Driven by fierce competition between firms in the sector, and in an attempt to reduce their reliance on government incentives, firms in the solar power sector have striven towards the two industry-level goals of reaching consumer grid parity, and making large-scale commercial solar power competitive. As discussed in this report, in order to achieve these goals, the solar PV industry needs to reduce the total cost of ownership of solar PV installations and simultaneously improve its power production efficiency. There have been substantial improvements in both areas, and grid parity in certain parts of Europe is said to be achievable by 2012. However, it will be a long time before solar power will become cost competitive with fossil-fuel power.

Despite recent growth, the solar power sector remains relatively immature. Attractive government incentives and an availability of cheap credit contributed to an acceleration in its industrial development and an inevitable swathe of new entrants joining the sector, predominantly downstream in the value chain where the barriers to entry are low and innovation and local knowledge provide firms with a competitive advantage. Other large, vertically and horizontally integrated firms have grown to become powerful forces in the industry and are likely to continue to dominate, particularly as the financial crisis and economic recession force weaker companies out of the market.

Irrespective of its immaturity the solar power sector has already developed to a point of sufficient scale that it is likely, in time, to begin to follow more conventional business cycles. For the short- to medium-term, demand in the sector will remain contingent on government

178 EPIA, Despite Credit Crunch the Solar Photovoltaic Industry is More Than Ever Ready for Further Growth, 15 April 2009. Available at <swww.epia.org/index.php?id=443&tx_ttnews[backPid]=3&tx_ttnews[tt_news]=5&cHash=1da5be1ea3>.

incentives, and any changes in the incentives will in all likelihood cause demand spikes and resultant stepped increases in supply capacity. Capacity mismatching will ease as the levelised generation cost of solar power falls. This will be driven by greater conversion efficiency and lower system ownership, which will in turn lower the reliance on government incentives to stimulate demand.

Through the financial crisis, economic recession and beyond, companies will continue to adopt different integration strategies in order to manage the conflicting strategic ambitions of securing benefits from improving core competencies as against the benefits of vertical integration. The sector is therefore unlikely to consolidate to a point where it is completely dominated by a small number of significantly large, vertically integrated firms. The barriers to entry provided by scale are weakened by the importance of technological improvement and in the longer term the sector is likely to start to resemble similar sectors where innovation and cost reduction increase access to the mass market.

Given the competitive advantage offered by greater conversion efficiency in solar power systems, disruptive technologies are likely to emerge, as they have in other industries, and large incumbent solar power firms will have to continue to invest heavily in R&D to try and stay ahead of the industry learning curve.

In summary, the solar PV sector is still in its infancy, but has developed incredibly quickly over the past five years. It is likely to consolidate somewhat through the financial crisis as healthy firms consume the weak, however, it will continue to attract new entrants keen to commercialise new technology. The competitiveness between firms will almost certainly drive the sector towards grid parity and, in time, the commercial, utility-scale production of solar power will become more economically viable.

# Appendix 1: Power Conversion Efficiencies Achieved by a Sample of Solar PV Companies

| | Solar Cells | |
|---|---|---|
| Company | Monocrystalline Silicon Cells | Polycrystalline Silicon Cells |
| Sunpower | 22.70% | - |
| Sanyo Solar | 19.30% | - |
| China Sunergy | 18.50% | 16.75% |
| JA Solar | 18.00% | 16.75% |
| Suntech | 18.00% | 16.00% |
| E-Ton Solar | 17.75% | 16.75% |
| CNPV | 17.60% | 16.40% |
| Neo Solar | - | 17.60% |
| Sunways | 17.50% | 16.50% |
| Ersol | 17.46% | 15.70% |
| Suniva Inc | 17.20% | - |
| Solarfun | 17.20% | 16.20% |
| Motech | - | 16.99% |
| Q-Cells | 16.80% | 16.60% |
| Solar Fabrik | 16.76% | - |
| Gintech | - | 16.50% |
| Solland | - | 16.40% |
| Solarwatt | 16.00% | 15.00% |
| Podolsky | 16.00% | - |
| Photovoltech | - | 16.00% |
| Kyocera Solar | - | 16.00% |
| REC | - | 15.80% |
| CTI Energy | 15.00% | 15.00% |

# Appendix 2: List of Sampled Solar PV Companies

| | Company Name | Foodstock | Ingots | Wafers | Cells | Modules | System Integrators | Year | Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Mitsubishi Electric | | 1 | 1 | 1 | 1 | 1 | 2009 | 28,165,231,170 | 829,391,097 | 2.94% |
| 2 | Sharp Group | | | 1 | 1 | 1 | | 2008 | 21,880,000,799 | -1,568,740,913 | -7.17% |
| 3 | AES Solar Energy BV | | | | | | 1 | 2008 | 11,819,652,839 | 2,023,389,232 | 17.12% |
| 4 | Mitsubishi Materials | 1 | | | | | | 2008 | 10,943,846,577 | 269,993,207 | 2.47% |
| 5 | Norsk Hydro | 1 | 1 | 1 | 1 | 1 | | 2008 | 10,018,761,938 | 134,950,326 | 1.35% |
| 6 | Wacker Chemie AG | 1 | 1 | 1 | | | | 2008 | 4,642,700,000 | 681,300,000 | 14.67% |
| 7 | Dow Corning (Hemlock Semicondutor) | 1 | | | | | | 2008 | 4,008,531,921 | 543,321,565 | 13.55% |
| 8 | Sumco Corporation | 1 | 1 | 1 | | | | 2008 | 3,012,390,762 | 345,810,164 | 11.48% |
| 9 | Tokuyama | 1 | | | | | | 2008 | 2,312,317,297 | 174,442,016 | 7.54% |
| 10 | Elecnor (Atersa SA) | | | | | 1 | 1 | 2008 | 1,911,000,000 | 138,000,000 | 7.22% |
| 11 | OCI Company Co. Ltd. | 1 | | | | | | 2008 | 1,617,870,714 | 280,718,934 | 17.35% |
| 12 | MEMC | 1 | 1 | 1 | | | | 2008 | 1,474,698,441 | 430,273,610 | 29.18% |
| 13 | Suntech Power Holdings Co., Ltd. | | | | 1 | 1 | 1 | 2008 | 1,406,295,969 | 64,724,919 | 4.60% |
| 14 | Q.Cells | 1 | 1 | 1 | 1 | 1 | 1 | 2008 | 1,251,300,000 | 205,100,000 | 16.39% |
| 15 | LDK Solar | 1 | 1 | 1 | | | | 2008 | 1,208,443,660 | 126,507,796 | 10.47% |
| 16 | SunPower Corporation | | 1 | 1 | 1 | 1 | 1 | 2008 | 1,055,397,911 | 123,909,238 | 11.74% |
| 17 | Elkem Solar AS | 1 | | | | | | 2008 | 1,010,319,066 | 106,468,348 | 10.54% |
| 18 | Conergy AG | | | | | 1 | 1 | 2008 | 1,006,200,000 | -212,500,000 | -21.12% |
| 19 | EniPower S.p.A. | | | | 1 | 1 | 1 | 2007 | 936,389,000 | 148,547,000 | 15.86% |
| 20 | REC | 1 | 1 | 1 | 1 | 1 | | 2008 | 925,777,321 | 494,930,886 | 53.46% |
| 21 | First Solar | | | | 1 | 1 | | 2008 | 916,667,402 | 341,276,846 | 37.23% |
| 22 | SolarWorld AG | 1 | 1 | 1 | 1 | 1 | 1 | 2008 | 900,311,000 | 260,800,000 | 28.97% |
| 23 | Solon SE | | | | | 1 | 1 | 2008 | 875,319,000 | 57,704,000 | 6.59% |
| 24 | SMA Solar Technology AG | | | | | | 1 | 2008 | 694,000,000 | 167,000,000 | 24.06% |
| 25 | Trina Solar Limited | | 1 | 1 | 1 | 1 | 1 | 2008 | 611,871,765 | 48,543,689 | 7.93% |
| 26 | JA Solar | | | | 1 | | | 2008 | 588,408,355 | 74,580,759 | 12.68% |
| 27 | Sanyo Solar | | 1 | 1 | 1 | 1 | | 2008 | 571,515,000 | 4,610,000 | 0.81% |
| 28 | Ibc Solar AG | | | | | 1 | 1 | 2007 | 558,860,000 | 25,243,000 | 4.52% |
| 29 | Goldbeck Solar GmbH | | | | | | 1 | 2007 | 550,000,000 | - | - |
| 30 | Solarfun | 1 | 1 | | 1 | 1 | | 2008 | 526,230,710 | -27,911,889 | -5.30% |
| 31 | Canadian Solar | | 1 | 1 | 1 | 1 | | 2008 | 521,476,905 | 0 | 0.00% |
| 32 | Motech | | 1 | 1 | 1 | 1 | 1 | 2008 | 509,556,270 | 61,657,668 | 12.10% |
| 33 | ReneSola | 1 | 1 | 1 | 1 | | | 2008 | 492,791,998 | -44,130,627 | -8.96% |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 34 | Schott Solar | 1 | 1 | 1 | 1 | 1 | | 2008 | 482,000,000 | 52,000,000 | 10.79% |
| 35 | Yingli Green Energy Holding Co., Ltd. | | 1 | 1 | 1 | 1 | 1 | 2008 | 437,464,760 | 73,232,930 | 16.74% |
| 36 | Phoenix Solar | | | | | | 1 | 2008 | 402,494,000 | 33,823,000 | 8.40% |
| 37 | Aleo Solar AG | | | | | 1 | | 2008 | 384,588,000 | 23,783,000 | 6.18% |
| 38 | E-ton Solar | | | 1 | 1 | | | 2008 | 370,369,545 | 34,105,652 | 9.21% |
| 39 | Kyocera | | 1 | 1 | 1 | 1 | 1 | 2007 | 361,000,000 | 32,260,000 | 8.94% |
| 40 | Centrosolar Group AG | | | | 1 | 1 | 1 | 2008 | 354,145,000 | 12,005,000 | 3.39% |
| 41 | Gintech | | | | 1 | | | 2008 | 352,818,487 | 50,048 | 0.01% |
| 42 | Ersol Solar Energy | 1 | 1 | 1 | 1 | 1 | | 2008 | 317,894,000 | 65,099,000 | 20.48% |
| 43 | PV Crystalox Solar plc | 1 | 1 | 1 | | | | 2008 | 274,095,000 | 147,223,000 | 52.10% |
| 44 | AEG Power Solutions | | | | | | 1 | 2007 | 270,593,000 | -2,018,000 | -0.75% |
| 45 | Sunways AG, Photovoltaic Technology | | | | 1 | 1 | 1 | 2008 | 262,341,000 | -2,681,000 | -1.02% |
| 46 | Isofoton | | | | 1 | 1 | 1 | 2007 | 259,950,000 | -21,174,000 | (-8.15%) |
| 47 | Neo Solar | | | | 1 | | | 2008 | 226,836,021 | 11,201,366 | 4.94% |
| 48 | Sovello A.G. | | | 1 | 1 | 1 | | 2008 | 219,000,000 | N/A | N/A |
| 49 | Solar Fabrik | | | 1 | 1 | 1 | | 2007 | 217,279,000 | -33,538,000 | -15.44% |
| 50 | China Sunergy (Nanjing) Co., Ltd. | | | | 1 | | | 2007 | 210,723,742 | 220,653 | 0.10% |
| 51 | systaic AG | | | | | | 1 | 2008 | 202,211,000 | 9,541,000 | 4.72% |
| 52 | 9Ren (Gamesa Solar) | | | | | 1 | 1 | 2007 | 200,000,000 | 26,000,000 | 13.00% |
| 53 | Solarwatt | | | | 1 | 1 | | 2007 | 194,362,000 | 5,433,000 | 2.80% |
| 54 | Scheuten Solar Holdings B.V. | | | | 1 | 1 | 1 | 2007 | 180,512,000 | 7,985,000 | 4.42% |
| 55 | Wagner & Co Solartechnik Gmbh | | | | | | 1 | 2008 | 166,664,000 | 4,729,000 | 2.84% |
| 56 | Intrakat | | | | | | 1 | 2008 | 152,000,000 | 3,900,000 | 2.57% |
| 57 | Juwi Solar GmbH | | | | | | 1 | 2007 | 147,977,000 | 9,226,000 | 6.23% |
| 58 | Photowatt Technologies | | 1 | 1 | 1 | 1 | 1 | 2008 | 146,084,878 | 4,633,716 | 3.17% |
| 59 | Tenesol | | | | | 1 | 1 | 2007 | 144,671,000 | 10,234,000 | 7.07% |
| 60 | Siliken SA | | | | | 1 | 1 | 2007 | 135,544,000 | 15,769,000 | 11.63% |
| 61 | Solaria | | | | | 1 | 1 | 2008 | 119,118,000 | -26,654,000 | -22.38% |
| 62 | Acciona Solar S.A. | | | | | | 1 | 2007 | 94,432,000 | 6,511,430 | 6.90% |
| 63 | Econcern - Ecostream International B.V. | | | | | | 1 | 2006 | 90,035,000 | -3,777,000 | -4.20% |
| 64 | Solar Ventures S.P.A | | | | | | 1 | 2007 | 86,354,000 | -735,016 | -0.85% |
| 65 | Solland Solar Energy B.V. | | | | 1 | | | 2007 | 84,235,000 | 4,226,000 | 5.02% |
| 66 | Evergreen Solar Inc. | | | 1 | 1 | 1 | | 2008 | 82,347,014 | -68,674,610 | -83.40% |
| 67 | Abastecimientos Energeticos S.L | | | | | | 1 | 2007 | 79,678,594 | 7,669,359 | 9.63% |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 68 | Photovoltech | | | | 1 | | | 2007 | 66,366,939 | 9,800,228 | 14.77% |
| 69 | Gunther Spelsberg GmbH + Co. KG | | | | | | 1 | 2007 | 42,501,000 | 10,234,000 | 24.08% |
| 70 | Topsil Semiconductor Material A/S | 1 | 1 | 1 | | | | 2008 | 38,858,424 | 8,614,050 | 22.17% |
| 71 | Albiasa Solar Sociedad Limitada. | | | | | | 1 | 2007 | 26,916,000 | 1,103,897 | 4.10% |
| 72 | Naps Systems Oy | | | | | | 1 | 2007 | 26,105,359 | 2,605,248 | 9.98% |
| 73 | CNPV Dongying (Half Year) | | 1 | 1 | 1 | 1 | 1 | 2008 | 17,703,612 | 930,118 | 5.25% |
| 74 | 3S Industries AG | | | | | 1 | | 2007 | 17,610,702 | 1,755,294 | 9.97% |
| 75 | EXEL GROUP S.A. (Solar Division) | | | | | 1 | | 2007 | 16,202,087 | 771,331 | 4.76% |
| 76 | Renergies Italia S.p.A | | | | | 1 | 1 | 2007 | 13,412,411 | 570,169 | 4.25% |
| 77 | Edisun Power Europe AG | | | | | | 1 | 2007 | 4,886,145 | 395,672 | 8.10% |
| 78 | United Solar Ovonic Europe GmbH | | | | | 1 | | 2008 | 2,190,860 | 126,831 | 5.79% |
| 79 | Martifer Solar S.A. | | | | | 1 | 1 | 2007 | 1,747,925 | 29,673 | 1.70% |
| 80 | Aries Solar Termoelectrica S.L. | | | | | | 1 | 2007 | 1,690,376 | -28,853 | -1.71% |
| 81 | Solaire Direct | | | | | 1 | 1 | 2007 | 1,553,000 | -892,000 | -57.44% |
| 82 | Dyesol UK Limited | | | | 1 | 1 | 1 | 2008 | 1,394,128 | 110,081 | 7.90% |
| 83 | Na'an Sanjing Silicon | 1 | | | | | | - | N/A | N/A | N/A |
| 84 | Solarcentury | | | | | | 1 | - | N/A | N/A | N/A |
| 85 | WIP - Renewable Energies | | | | | | 1 | - | N/A | N/A | N/A |
| 86 | Energy Solutions S.A. | | | | | 1 | | - | N/A | N/A | N/A |
| 87 | Bisol d.o.o. | | | | | 1 | | - | N/A | N/A | N/A |
| 88 | BG Solar Panels Ltd. | | | | | 1 | | - | N/A | N/A | N/A |
| 89 | Suniva Inc. | | | | 1 | | | - | N/A | N/A | N/A |
| 90 | City Solar | | | | | | 1 | - | N/A | N/A | N/A |
| 91 | Meridian Neue Energien GmbH | | | | | | 1 | - | N/A | N/A | N/A |
| 92 | Beck Energy | | | | | | 1 | - | N/A | N/A | N/A |
| 93 | Tauber Solar | | | | | | 1 | - | N/A | N/A | N/A |
| 94 | Gehrlicher Solar AG. | | | | | | 1 | - | N/A | N/A | N/A |
| 95 | Avanzalia | | | | | | 1 | - | N/A | N/A | N/A |
| 96 | Geosol | | | | | | 1 | - | N/A | N/A | N/A |
| 97 | Flixsolar | | | | | | 1 | - | N/A | N/A | N/A |
| 98 | Solartia | | | | | | 1 | - | N/A | N/A | N/A |
| 99 | Idesa | | | | | | 1 | - | N/A | N/A | N/A |
| 100 | Solarpro JSCo. | | | | | 1 | 1 | | N/A | N/A | N/A |
| 101 | Bangkok Solar Co., Ltd. | | | | | 1 | 1 | | N/A | N/A | N/A |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 102 | Pillar JSC | | 1 | 1 | | | | | N/A | N/A | N/A |
| 103 | Piritium S.A. | | 1 | 1 | | | | | N/A | N/A | N/A |
| 104 | Swiss Wafer | | 1 | 1 | | | | | N/A | N/A | N/A |
| 105 | CTI Energy Products Limited | | | | 1 | 1 | | | N/A | N/A | N/A |
| 106 | Silcio S.A. | | | | 1 | 1 | | | N/A | N/A | N/A |
| 107 | Podolsky Chemical & Metallurgical | | 1 | 1 | 1 | | | - | N/A | N/A | N/A |
| 108 | BP Solar (Subsidiary of the BP Group) | 1 | 1 | 1 | 1 | 1 | 1 | - | N/A | N/A | N/A |
| | Total | 20 | 29 | 33 | 43 | 53 | 61 | | | | |

# Appendix 3: Specialist Company Sample

| | Company Name | Foodstock | Ingots | Wafers | Cells | Modules | System Integrators | Year | Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AES Solar Energy BV | | | | | | 1 | 2008 | 11,819,652,839 | 2,023,389,232 | 17.12% |
| 2 | Mitsubishi Materials | 1 | | | | | | 2008 | 10,943,846,577 | 269,993,207 | 2.47% |
| 3 | Dow Corning (Hemlock Semicondutor) | 1 | | | | | | 2008 | 4,008,531,921 | 543,321,565 | 13.55% |
| 4 | Tokuyama | 1 | | | | | | 2008 | 2,312,317,297 | 174,442,016 | 7.54% |
| 5 | OCI Company Co. Ltd. | 1 | | | | | | 2008 | 1,617,870,714 | 280,718,934 | 17.35% |
| 6 | Elkem Solar AS | 1 | | | | | | 2008 | 1,010,319,066 | 106,468,348 | 10.54% |
| 7 | SMA Solar Technology AG | | | | | | 1 | 2008 | 694,000,000 | 167,000,000 | 24.06% |
| 8 | JA Solar | | | | 1 | | | 2008 | 588,408,355 | 74,580,759 | 12.68% |
| 9 | Goldbeck Solar GmbH | | | | | | 1 | 2007 | 550,000,000 | - | - |
| 10 | Phoenix Solar | | | | | | 1 | 2008 | 402,494,000 | 33,823,000 | 8.40% |
| 11 | Aleo Solar AG | | | | | 1 | | 2008 | 384,588,000 | 23,783,000 | 6.18% |
| 12 | Gintech | | | | 1 | | | 2008 | 352,818,487 | 50,048 | 0.01% |
| 13 | AEG Power Solutions | | | | | | 1 | 2007 | 270,593,000 | -2,018,000 | -0.75% |
| 14 | Neo Solar | | | | 1 | | | 2008 | 226,836,021 | 11,201,366 | 4.94% |
| 15 | China Sunergy (Nanjing) Co., Ltd. | | | | 1 | | | 2007 | 210,723,742 | 220,653 | 0.10% |
| 16 | systaic AG | | | | | | 1 | 2008 | 202,211,000 | 9,541,000 | 4.72% |
| 17 | Wagner & Co Solartechnik Gmbh | | | | | | 1 | 2008 | 166,664,000 | 4,729,000 | 2.84% |
| 18 | Intrakat | | | | | | 1 | 2008 | 152,000,000 | 3,900,000 | 2.57% |
| 19 | Juwi Solar GmbH | | | | | | 1 | 2007 | 147,977,000 | 9,226,000 | 6.23% |
| 20 | Acciona Solar S.A. | | | | | | 1 | 2007 | 94,432,000 | 6,511,430 | 6.90% |
| 21 | Econcern - Ecostream International B.V. | | | | | | 1 | 2006 | 90,035,000 | -3,777,000 | -4.20% |
| 22 | Solar Ventures S.P.A | | | | | | 1 | 2007 | 86,354,000 | -735,016 | -0.85% |
| 23 | Solland Solar Energy B.V. | | | | 1 | | | 2007 | 84,235,000 | 4,226,000 | 5.02% |
| 24 | Abastecimientos Energeticos S.L | | | | | | 1 | 2007 | 79,678,594 | 7,669,359 | 9.63% |
| 25 | Photovoltech | | | | 1 | | | 2007 | 66,366,939 | 9,800,228 | 14.77% |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | Gunther Spelsberg GmbH + Co. KG | | | | | | 1 | 2007 | 42,501,000 | 10,234,000 | 24.08% |
| 27 | Albiasa Solar Sociedad Limitada. | | | | | | 1 | 2007 | 26,916,000 | 1,103,897 | 4.10% |
| 28 | Naps Systems Oy | | | | | | 1 | 2007 | 26,105,359 | 2,605,248 | 9.98% |
| 29 | 3S Industries AG | | | | | 1 | | 2007 | 17,610,702 | 1,755,294 | 9.97% |
| 30 | EXEL GROUP S.A. (Solar Division) | | | | | 1 | | 2007 | 16,202,087 | 771,331 | 4.76% |
| 31 | Edisun Power Europe AG | | | | | | 1 | 2007 | 4,886,145 | 395,672 | 8.10% |
| 32 | United Solar Ovonic Europe GmbH | | | | | 1 | | 2008 | 2,190,860 | 126,831 | 5.79% |
| 33 | Aries Solar Termoelectrica S.L. | | | | | | 1 | 2007 | 1,690,376 | -28,853 | -1.71% |
| 34 | Na'an Sanjing Silicon | 1 | | | | | | - | N/A | N/A | N/A |
| 35 | Solarcentury | | | | | | 1 | - | N/A | N/A | N/A |
| 36 | WIP - Renewable Energies | | | | | | 1 | - | N/A | N/A | N/A |
| 37 | Energy Solutions S.A. | | | | | 1 | | - | N/A | N/A | N/A |
| 38 | Bisol d.o.o. | | | | | 1 | | - | N/A | N/A | N/A |
| 39 | BG Solar Panels Ltd. | | | | | 1 | | - | N/A | N/A | N/A |
| 40 | Suniva Inc. | | | | 1 | | | - | N/A | N/A | N/A |
| 41 | City Solar | | | | | | 1 | - | N/A | N/A | N/A |
| 42 | Meridian Neue Energien GmbH | | | | | | 1 | - | N/A | N/A | N/A |
| 43 | Beck Energy | | | | | | 1 | - | N/A | N/A | N/A |
| 44 | Tauber Solar | | | | | | 1 | - | N/A | N/A | N/A |
| 45 | Gehrlicher Solar AG. | | | | | | 1 | - | N/A | N/A | N/A |
| 46 | Avanzalia | | | | | | 1 | - | N/A | N/A | N/A |
| 47 | Geosol | | | | | | 1 | - | N/A | N/A | N/A |
| 48 | Flixsolar | | | | | | 1 | - | N/A | N/A | N/A |
| 49 | Solartia | | | | | | 1 | - | N/A | N/A | N/A |
| 50 | Idesa | | | | | | 1 | - | N/A | N/A | N/A |
| | Total | 6 | 0 | 0 | 7 | 7 | 30 | | | | |

# Appendix 4: Specialist-Integrator Company Sample

| | Company Name | Foodstock | Ingots | Wafers | Cells | Modules | System Integrators | Year | Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Elecnor (Atersa SA) | | | | | 1 | 1 | 2008 | 1,911,000,000 | 138,000,000 | 7.22% |
| 2 | Conergy AG | | | | | 1 | 1 | 2008 | 1,006,200,000 | -212,500,000 | -21.12% |
| 3 | First Solar | | | | 1 | 1 | | 2008 | 916,667,402 | 341,276,846 | 37.23% |
| 4 | Solon SE | | | | | 1 | 1 | 2008 | 875,319,000 | 57,704,000 | 6.59% |
| 5 | Ibc Solar AG | | | | | 1 | 1 | 2007 | 558,860,000 | 25,243,000 | 4.52% |
| 6 | E-ton Solar | | | 1 | 1 | | | 2008 | 370,369,545 | 34,105,652 | 9.21% |
| 7 | 9Ren (Gamesa Solar) | | | | | 1 | 1 | 2007 | 200,000,000 | 26,000,000 | 13.00% |
| 8 | Solarwatt | | | | 1 | 1 | | 2007 | 194,362,000 | 5,433,000 | 2.80% |
| 9 | Tenesol | | | | | 1 | 1 | 2007 | 144,671,000 | 10,234,000 | 7.07% |
| 10 | Siliken SA | | | | | 1 | 1 | 2007 | 135,544,000 | 15,769,000 | 11.63% |
| 11 | Solaria | | | | | 1 | 1 | 2008 | 119,118,000 | -26,654,000 | -2238.00% |
| 12 | Renergies Italia S.p.A | | | | | 1 | 1 | 2007 | 13,412,411 | 570,169 | 4.25% |
| 13 | Martifer Solar S.A. | | | | | 1 | 1 | 2007 | 1,747,925 | 29,673 | 1.70% |
| 14 | Solaire Direct | | | | | 1 | 1 | 2007 | 1,553,000 | -892,000 | -57.44% |
| 15 | Solarpro JSCo. | | | | | 1 | 1 | | N/A | N/A | N/A |
| 16 | Bangkok Solar Co., Ltd. | | | | | 1 | 1 | | N/A | N/A | N/A |
| 17 | Pillar JSC | | 1 | 1 | | | | | N/A | N/A | N/A |
| 18 | Piritium S.A. | | 1 | 1 | | | | | N/A | N/A | N/A |
| 19 | Swiss Wafer | | 1 | 1 | | | | | N/A | N/A | N/A |
| 20 | CTI Energy | | | | 1 | 1 | | | N/A | N/A | N/A |
| 21 | Silcio S.A. | | | | 1 | 1 | | | N/A | N/A | N/A |
| | Total | 0 | 3 | 4 | 5 | 17 | 13 | | | | |

# Appendix 5: Partial-Integrator Company Sample

| | Company Name | Foodstock | Ingots | Wafers | Cells | Modules | System Integrators | Year | Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Sharp Group | | | 1 | 1 | 1 | | 2008 | 21,880,000,799 | -1,568,740,913 | -7.17% |
| 2 | Wacker Chemie AG | 1 | 1 | 1 | | | | 2008 | 4,642,700,000 | 681,300,000 | 14.67% |
| 3 | Sumco Corporation | 1 | 1 | 1 | | | | 2008 | 3,012,390,762 | 345,810,164 | 11.48% |
| 4 | MEMC | 1 | 1 | 1 | | | | 2008 | 1,474,698,441 | 430,273,610 | 29.18% |
| 5 | Suntech Power Holdings Co., | | | | 1 | 1 | 1 | 2008 | 1,406,295,969 | 64,724,919 | 4.60% |
| 6 | LDK Solar | 1 | 1 | 1 | | | | 2008 | 1,208,443,660 | 126,507,796 | 10.47% |
| 7 | EniPower S.p.A. | | | | 1 | 1 | 1 | 2007 | 936,389,000 | 148,547,000 | 15.86% |
| 8 | Sanyo Solar | | 1 | 1 | 1 | 1 | | 2008 | 571,515,000 | 4,610,000 | 0.81% |
| 9 | Solarfun | 1 | 1 | | 1 | 1 | | 2008 | 526,230,710 | -27,911,889 | -5.30% |
| 10 | Canadian Solar | | 1 | 1 | 1 | 1 | | 2008 | 521,476,905 | 0 | 0.00% |
| 11 | ReneSola | 1 | 1 | 1 | 1 | | | 2008 | 492,791,998 | -44,130,627 | -8.96% |
| 12 | Centrosolar Group AG | | | | 1 | 1 | 1 | 2008 | 354,145,000 | 12,005,000 | 3.39% |
| 13 | PV Crystalox Solar plc | 1 | 1 | 1 | | | | 2008 | 274,095,000 | 147,223,000 | 52.10% |
| 14 | Sunways AG, Photovoltaic | | | | 1 | 1 | 1 | 2008 | 262,341,000 | -2,681,000 | -1.02% |
| 15 | Isofoton | | | | 1 | 1 | 1 | 2007 | 259,950,000 | -21,174,000 | (-8.15%) |
| 16 | Sovello A.G. | | | 1 | 1 | 1 | | 2008 | 219,000,000 | N/A | N/A |
| 17 | Solar Fabrik | | | 1 | 1 | 1 | | 2007 | 217,279,000 | -33,538,000 | -15.44% |
| 18 | Scheuten Solar Holdings B.V. | | | | 1 | 1 | 1 | 2007 | 180,512,000 | 7,985,000 | 4.42% |
| 19 | Evergreen Solar Inc. | | | 1 | 1 | 1 | | 2008 | 82,347,014 | -68,674,610 | -83.40% |
| 20 | Topsil Semiconductor Material | 1 | 1 | 1 | | | | 2008 | 38,858,424 | 8,614,050 | 22.17% |
| 21 | Dyesol UK Limited | | | | 1 | 1 | 1 | 2008 | 1,394,128 | 110,081 | 7.90% |
| 22 | Podolsky Chemical | | 1 | 1 | 1 | | | - | N/A | N/A | N/A |

# Appendix 6: Full Integrator Company Sample

| | Company Name | Foodstock | Ingots | Wafers | Cells | Modules | System Integrators | Year | Operating Revenue (EUR) | Operating Profit (EUR) | Operating Profit % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Mitsubishi Electric | | 1 | 1 | 1 | 1 | 1 | 2009 | 28,165,231,170 | 829,391,097 | 2.94% |
| 2 | Norsk Hydro | 1 | 1 | 1 | 1 | 1 | | 2008 | 10,018,761,938 | 134,950,326 | 1.35% |
| 3 | Q.Cells | 1 | 1 | 1 | 1 | 1 | 1 | 2008 | 1,251,300,000 | 205,100,000 | 16.39% |
| 4 | SunPower Corporation | | 1 | 1 | 1 | 1 | 1 | 2008 | 1,055,397,911 | 123,909,238 | 11.74% |
| 5 | REC | 1 | 1 | 1 | 1 | 1 | | 2008 | 925,777,321 | 494,930,886 | 53.46% |
| 6 | SolarWorld AG | 1 | 1 | 1 | 1 | 1 | 1 | 2008 | 900,311,000 | 260,800,000 | 28.97% |
| 7 | Trina Solar Limited | | 1 | 1 | 1 | 1 | 1 | 2008 | 611,871,765 | 48,543,689 | 7.93% |
| 8 | Motech | | 1 | 1 | 1 | 1 | 1 | 2008 | 509,556,270 | 61,657,668 | 12.10% |
| 9 | Schott Solar | 1 | 1 | 1 | 1 | 1 | | 2008 | 482,000,000 | 52,000,000 | 10.79% |
| 10 | Yingli Green Energy Holding Co., Ltd. | | 1 | 1 | 1 | 1 | 1 | 2008 | 437,464,760 | 73,232,930 | 16.74% |
| 11 | Kyocera | | 1 | 1 | 1 | 1 | 1 | 2007 | 361,000,000 | 32,260,000 | 8.94% |
| 12 | Ersol Solar Energy | 1 | 1 | 1 | 1 | 1 | | 2008 | 317,894,000 | 65,099,000 | 20.48% |
| 13 | Photowatt Technologies | | 1 | 1 | 1 | 1 | 1 | 2008 | 146,084,878 | 4,633,716 | 3.17% |
| 14 | CNPV Dongying Photovoltaic (Half Year) | | 1 | 1 | 1 | 1 | 1 | 2008 | 17,703,612 | 930,118 | 5.25% |
| 15 | BP Solar (Subsidiary of the BP Group) | 1 | 1 | 1 | 1 | 1 | 1 | - | N/A | N/A | N/A |
| | Total | 7 | 15 | 15 | 15 | 15 | 11 | | | | |

# Glossary

| | |
|---|---|
| Balance of system (BOS) | BOS has traditionally referred to the additional material inputs required to make a solar module or array operational. This includes the inverter and all other physical inputs such as the structural foundations, frames, mounts, solar trackers and electrical wiring. More recently the term has increasingly been used to refer to all cost items from installation to ongoing operation and maintenance. |
| Base load | The minimum level of power demand on a system over 24 hours. This demand is met by "base-load plants" that can supply power at a steady rate. These often run on nuclear, hydro, coal, etc. |
| Baseline scenario | The baseline scenario is a "business-as-usual" scenario in which current trends are assumed to continue into the future. In this report the baseline scenarios comes from the EU, or from national governments where indicated. |
| Building-integrated photovoltaics (BIPV) | BIPV is the integration of photovoltaic modules into the envelope of a building, such as the roof or façade |
| Capacity | The rated output of a power generation unit. |
| Capacity charge | A charge set by the grid operator to use the power grid for power transmission. |
| Concentrated solar-thermal plant | An electricity-generating plant that uses mirrors or lenses to focus the heat from sunlight onto a small area to generate electricity. |
| Concentrated solar PV | Use of mirrors or lenses to focus the sunlight onto a PV array. This can be a more efficient way to use *solar PV* panels. |
| Conversion efficiency | The percentage of potential energy that is turned into actual energy. For example, in solar PV, only about 15 to 20 per cent of solar energy is transformed into electricity. |
| Cost of ownership | The total costs incurred throughout the life of the project. This includes project cost, operation and maintenance costs and decommissioning costs. |
| Crystalline silicon | The raw material in manufacturing crystalline solar PV modules. |
| Deep costs for grid connection | The developer has to pay not only for the physical link to the power grid, but also for all enhancements and upgrades to the grid necessary for the grid's reliability and stability. See also *shallow costs for grid connection*. |

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| Degression | Successively lower rates or amounts. In this report, it is applied to electricity tariffs that decrease at a set amount every year. |
| Distribution system operator (DSO) | The DSO manages the low- and medium-voltage power network that transmits and distributes electricity from the high-voltage grid run by the transmission system operator to customers. Smaller generators can be directly connected to the low- or medium-voltage grid. According to EU regulations, DSOs must be run independently of generators and suppliers, in other words they must be *legally unbundled*. |
| Feed-in tariff (FIT) | A primary support mechanism used by governments to promote renewable electricity development. It generally offers price guarantees for a set period of time and a system of obligatory purchase of all power by a network operator. See premium and *tradable green certificates* for comparison. |
| Final energy consumption | Energy supplied to the final consumer's door for all uses, including industry, transport, households, services, agriculture, forestry, and fisheries. In the electricity sector this includes the losses in electricity production and distribution. Generally measured in tonnes of oil equivalent (toe). The EU's renewable energy targets are based on final energy consumption. See also *primary energy consumption*. |
| Fixed premium | A fixed premium, sometimes called a Green Bonus, is a set value that renewable electricity generators receive in addition to the sales price (or market price) of electricity. Therefore, the net generation compensation is the sales or market price of electricity plus this fixed premium. See *variable premium* for comparison. |
| Generation | In this report, it means production of electricity. |
| Generating capacity | *See capacity.* |
| Generation compensation | The total amount of compensation that a generator receives for their power output. In this report, this includes, where appropriate, the market price of electricity plus operating incentives. |
| Grid connection fees | This covers all the fees for a generator to be connected to the grid and to use the grid. These include connection and entry fees but not grid usage charges. Grid connection fees and procedures vary greatly among countries and are highlighted in the report when they affect renewable electricity development. |

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| Grid parity | A situation where the levelised ownership cost of generating electricity using a solar PV system is equal to or less than the retail electricity price paid by consumers. |
| Gross inland energy consumption | Quantity of all energy consumed within the borders, including imports. It is a measure of all energy sources before they are converted into energy. Generally measured in tonnes of oil equivalent (toe). The same as *primary energy consumption*. |
| Incentives | Government programmes to promote the development of renewable energy. See also *primary support mechanism*. |
| Ingots | The raw silicon produced. Silicon ingots are generally cut into *wafers*. |
| Installed capacity | Power generating capacity measured in Watts. See also *generation* and *peak demand*. |
| Interconnector | A physical connection between separate grids (in general between different countries) to allow for the import and export of electricity. |
| Inverters | Solar PV systems produce DC (direct current power). Inverters are used to convert that power to AC (alternating current), the form used by consumers. |
| Levelised generation cost | The average generation cost of a power station. Generally established using a levelised lifetime cost methodology which factors in the discounted investment, operation and maintenance and fuel expenditures for a year, divided by the electricity generated during the same period, similarly discounted. Transmission and grid charges are not included. In this report, the levelised generation costs are sourced from an IEA/OECD 2005 report, unless otherwise specified.[a] |
| Load hours | The number of hours for which a generator delivered electricity. Full load hours refers to the amount of time for which a generator is delivering its fullest possible load of electricity. For example, a 1 MW wind turbine that generates 1 MWh of electricity has 1 full load hour. |
| Monocrystalline silicon | High quality crystalline silicon created around one crystal. See also *polycrystalline silicon*. |
| Microgeneration | Small-scale electricity generation, usually for private use, although if surplus electricity is created it can be sold to the network. In the UK it is defined as having a maximum capacity of 50 kW. |

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| Obligatory purchase | In this report, the policy that a network operator or utility has to purchase all the output of a renewable electricity generating installation regardless of demand. Generally found with a *feed-in tariff* incentive. |
| Off-peak hours | The period of day when demand for power is at the lowest (generally at night). |
| Peak demand | The highest power demand on a system. In this report, the highest demand in a year. |
| Peak hours | The period of day when demand for power is the highest. |
| Polycrystalline silicon (polysilicon) | Crystalline silicon created using many crystals. Polycrystalline silicon costs less to produce than *monocrystalline silicon* but is of lower quality. Due to costs, most solar PV modules are produced with polycrystalline silicon. Usually referred to as polysilicon. |
| Premium | An operating incentive where renewable electricity generators receive a government-set supplement in addition to the sales or market price of electricity per unit of output sold. Unlike the FIT there is no system of obligatory purchase. There are generally two types: *fixed* and *variable premiums*. |
| Primary energy consumption | Sometimes referred to as gross *inland consumption of energy*. The quantity of all energy consumed within the borders, including imports. It is a measure of all energy sources before they are converted into energy. Generally measured in tonnes of oil equivalent (toe). |
| Primary support mechanism | The main incentive programme of the government to promote renewable electricity development. In the EU, it includes *feed-in tariffs (FITs), premiums and tradable green certificates*. |
| Renewable electricity | Electricity generated from a renewable energy source. |
| Renewable energy | Renewable energy is any form of energy (electricity, heat, transportation fuels, etc.) produced by renewable energy sources such as hydro, wind, biomass, wave and tidal, solar, and geothermal. |
| Shallow costs for grid connection | The developer is only charged for constructing a line to the first grid connection point and not for the grid enhancement that may be necessary for the connection. See also *deep costs for grid connection*. |
| Silicon | The raw material of silicon-based solar cells. The silicon produced can be *polycrystalline or monocrystalline silicon*. |

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| Solar cells | A device that converts solar radiation into electricity. Solar cells can be thin-film cells or silicon-based cells. A number of solar cells are generally grouped together to form a *solar module*. |
| Solar irradiation | The amount of solar radiation falling on a particular location. |
| Solar module | A group of interconnected solar cells enclosed in an environmentally sealed unit. Solar modules are made up of a transparent material on the front of the module (solar cells), a back cover material and generally a frame or casing unit. |
| Solar PV (photovoltaic) | The direct conversion of sunlight into electricity. |
| Suppliers | Those who sell electricity to end users. |
| System integrators | Companies that construct solar PV power installations. |
| Thin film | A new type of *solar PV* panel that uses less silicon than traditional PV panels. |
| Trackers | Devices that move a solar module so that the module is always facing the sun. Trackers can be single-axis (moving either horizontally or vertically) or dual-axis (moving both horizontally and vertically). The use of trackers increases the output of solar PV systems |
| Tradable green certificates | A *primary support mechanism* in which renewable electricity generators are awarded certificates for their power generation from renewable sources. Suppliers or distributors have a quota obligation for renewable energy and need to buy the certificates to prove they have met their quota. |
| Transmission system operator (TSO) | The high-voltage electricity grid operator. The high-voltage grid transmits electricity generally between generators and distributors over long distances. Under EU rules, the transmission system operator has to be *unbundled*. |

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| Unbundling | In this report, it specifically refers to the EU-mandated structural separation of the operation of the power transmission networks from the generation and supply of power. There are various levels of unbundling, which include:<br>• Functional unbundling: The transmission system operator is owned by a larger conglomerate, but is housed in an independent business unit.<br>• Legal unbundling: The transmission and distribution companies might remain majority-owned by a larger power conglomerate, but are housed in independent companies.<br>• Ownership unbundling: Separate ownership of the network operators from activities related to generation or supply of electricity. Minority ownership may be retained by larger power conglomerates.<br><br>Under EU legislation, transmission and distribution system operators have to be legally unbundled. |
| Variable premium | A *premium* system in which the generation compensation is capped at a set amount. The variable premium fills in the gap between the market price of electricity and the set amount and hence the variable premium will change with the market price of electricity. |
| Vertical integration | The control of one company or group over the upstream supply of its inputs and the downstream sales and distribution of its outputs. A limited interpretation of vertical integration considers only a firm's complete ownership control over different stages of the value chain. This is achieved either through acquisition of a company by another, or through the expansion of a company's production and manufacturing business lines. In this report vertical integration refers to the ultimate operational control a company or group has over business units or group companies at different stages of the value chain. |
| Wafers | Thin slices of silicon produced from the *ingots* of silicon. The wafers are then used to produce silicon-based *solar cells*. |
| Wholesale electricity market | The purchase and sale of electricity from generators to resellers on the open market. |

Notes: [a] For more information, see OECD, IEA, NEA, Projected Costs for Generating Electricity, 2005 Update. Available at <www.iea.org/textbase/nppdf/free/2005/ElecCost.pdf>. Reproduced in Commission of the European Communities, Towards a Low Carbon Future: European Strategic Energy Technology Plan, MEMO/07/493, 22 November 2007. Available at <europa.eu/rapid/pressReleasesAction.do?reference=MEMO/07/493>.
Sources: For a detailed glossary see the Energy Information Agency, Glossary of Electricity Terms. Available at <www.eia.doe.gov/cneaf/electricity/epav1/glossary.html >.

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