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## Pvresources annual review displays development of utility-scale PV power plants: all-time records in capacity and growth in 2008

by Denis Lenardic and Rolf Hug

2008 was characterised by numerous projects of MW-range photovoltaic (PV) power plants, and it was also the year with the highest market growth related to large-scale photovoltaic systems ever. Not only in Spain, where progress is abundantly clear, but in some other countries the cumulative installed power increased significantly. In the European Union progress was, among others, observed in Italy, the Czech Republic and France; the German market decreased slightly, but due to the market explosion in Spain the installed power from 2008 still reached the level of the previous year.

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Lucainena de las Torres PV power plant, Andalusia, Spain (courtesy: MEPSolar)



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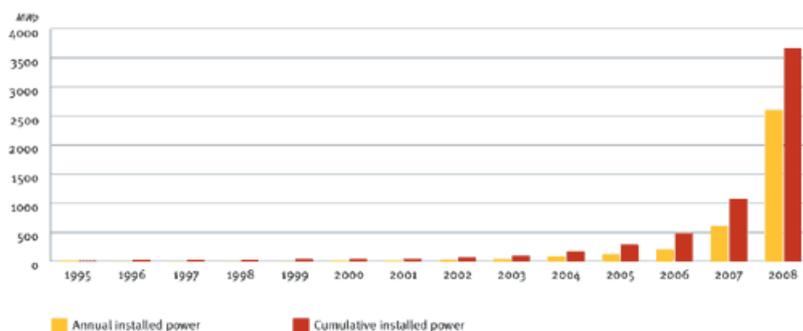
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Previously released in January 2008 and revised in April 2008, the pvresources.com Annual Report 2007 was among the first publicly available reports just to present basic statistical data about the majority of large-scale photovoltaic power plants worldwide. The new annual review for 2008 is much more ambitious than the previous one, targeting professional readers including policy makers, market researchers, consultancy organisations, scientists and others. In cooperation with pvresources.com solarserver.com, German and international portal site on renewable and solar energy, highlights the key findings on installed capacity, capacity by region / country, solar cell and mounting technologies, Investment costs and electricity price in the special solar report of may 2009.

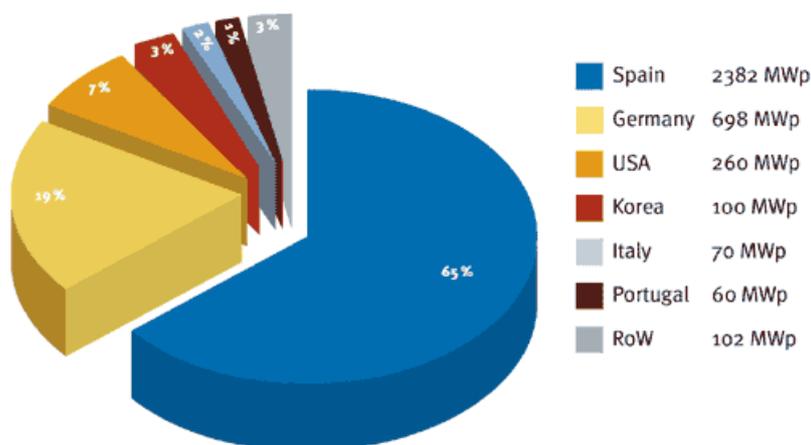
## Large-scale photovoltaic power plants: Cumulative capacity tripled in 2008; hyper growth in annual installations

Pvresources.com's database includes more than 1,900 large-scale photovoltaic power plants (put into service in 2008 or earlier), each with a peak power of 200 kWp or more.



Annual installed and cumulative capacity of large-scale, grid-connected photovoltaic power plants in the period from 1995 to 2008.

The cumulative power of all these photovoltaic power plants is more than 3.6 GWp. The average capacity of the plants is slightly above 1.8 MWp. More than 750 of these large-scale photovoltaic plants are located in Spain, the number of plants in Germany is exceeding 500 and more than 370 are based in the USA.



Large-scale photovoltaic power plants – estimated power capacity by country as of December 2008.

Significant increases in the numbers of new photovoltaic power plants are closely related with time periods when favourable subsidies were possible – most notably for Germany, Spain, Korea and California.

In 2008, more than 1000 large-scale PV plants were constructed and put



into service worldwide. Many of these plants consist of several stages where each stage can be considered as a unique power plant, so the actual number is even higher. In Spain about 600 large-scale PV plants were brought on line, more than 120 for each Germany and the USA. Among other countries in Belgium and the Czech Republic several large-scale roof-mounted PV plants (Belgium) and ground-mounted systems (Czech Republic) were constructed. Regarding large-scale PV power plants Korea took on a leading role in Asia. Several MW-range power plants were put into service in Korea last year. Europe still is by far the most advanced region with more than 800 large-scale PV plants connected to the electricity grid in 2008. In Europe more than 1500 large-scale PV power plants are currently operating, followed by the USA with about 400 PV plants.



Left: Solar PV power Plant Olivenza, Spain. Courtesy: SunPower Corp. Right: PV power plant Calvià , Mallorca, Spain. Courtesy: : MPC Capital Gruppe; MPC Capital AG

### Megawatt plants representing three-fourths of installed large-scale PV power plants capacity worldwide

The definite market leader in 2008 was Spain with more than 2 GWp installed. The most important markets were Spain, Germany, the USA (California) and Korea. Power plants with 10 MWp or more contributed about 1 GWp to the new power capacity installed in 2008. Power plants with 3 MW or more represent over 50 % of installed power worldwide. MW range power plants however represent more than 75 % of worldwide installed power (please note that this market shares are related only to large-scale PV power plants).

### Uppermost power capacity per capita in southern Spain and the German states of Bavaria and Saxony

Due to different population densities, significant differences in PV power capacity installed per capita between countries, regions or provinces have been observed. The largest figures for power capacity per capita are reached in the Spanish regions of Andalusia, Castile-La Mancha and Extremadura. In Germany the states of Bavaria and Saxony are leading regarding power capacity per capita.

Autonomous Community	Power per capita installed (Wp/capita)
Andalusia	63
Aragon	60
Castilla-La Mancha	360
Extremadura	339
La Rioja	135
Murcia	>115
Navarra	210

Estimated power capacity per capita related to large scale PV power plants and installed in some Spanish autonomous communities as at December 2008 \*only autonomous communities with more than 60 Wp per capita installed are listed - all numbers related to large-scale PV power plants only.

State	Power per capita Installed (Wp/capita)
Bavaria	>25
Rhineland-Palatinate	17
Saarland	20
Saxony	20
Saxony-Anhalt	14
Thuringia	>13

Estimated power capacity per capita installed in some German states as at December 2008 \*only states with more than 10 Wp per capita installed are listed all numbers related to large-scale PV power plants only.

Among the Asian countries Korea takes the leading role with most power capacity per capita installed in its Southern Jeolla Province where this figure has reached a similar level as in Bavaria, Germany. In the USA the highest power capacity per capita is installed in California, but due to the high population density, this value is still much lower than in the previously mentioned regions.

### Solar cell technologies: crystalline silicon prevailing, thin film on the rise

The estimated market share of solar cell technologies is based on available data (the technology used) of about 1,100 large-scale PV power plants. The amount of information from these samples represents a relatively large part of pvresources database, so statistical data on technology market share for other plants in the database, which includes about 2,000 PV power plants, were interpolated with a high degree of accuracy.

The majority of solar power plants were based on crystalline silicon (c-Si) solar cells (modules). Other commonly installed technologies include amorphous silicon (a-Si), cadmium telluride (CdTe), microcrystalline silicon ( $\mu\text{c-Si}$ ) and copper indium selenide (CIS or CIGS) modules. Until 2002, wafer-based crystalline silicon solar cells were almost the only solar cell technology used in large-scale power plants. Since then, steady growth in the share of thin-film technologies has been observed. Still crystalline silicon remains prevalent and is the most important technology for utility-scale PV power plants.



Left: Power plant with cadmium telluride (CdTe) modules (Waldpolenz; Germany). Right: Plant using CIS panels at Albacete (Spain)

In Germany market share of CdTe modules significantly increased in the last three years. In 2006, CdTe modules represented a market share of about 25 %. In the last two years market share has increased by up to 50 %. Due to competitive pricing, CdTe modules were used for several of the largest ground mounted power plants in Germany, consequently such a large market share is not a surprise. An increase of CdTe market share was also observed last year in other countries such as Spain, the USA and France. Similar market share increases related to thin-film technologies have been observed in the Czech Republic too. However the main thin-film technology currently used in the Czech Republic is amorphous Silicon (a-Si).

## Increasing market share of tracking arrays

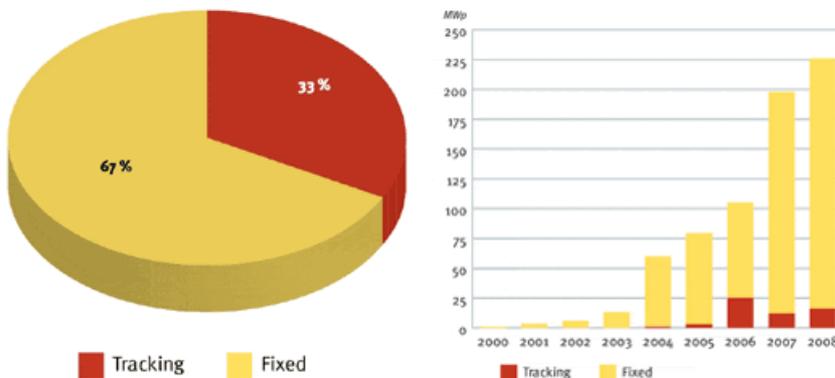
The use of tracking arrays is almost exclusively limited to ground mounted power plants, most of them are located in Spain, followed by Germany and the USA.



Tracking arrays represent a market share (power related) of more than 30 % and almost exclusively use c-Si modules. Other types of modules requiring greater area are very scarcely used in tracking applications.

Two-axis trackers in Spain (courtesy: Suravia)

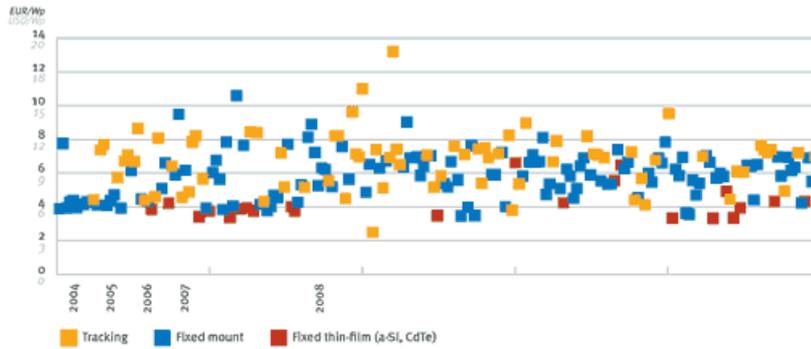
From less than 10 % market share in 2004, tracking installations increased to approximately 40 % annual share by 2008.



Left: Estimated market share of tracking and fixed mounted arrays worldwide as at December 2008. Right: Estimated annually installed power capacity (MWp) in Germany – sorted by mounting type in the period from 2000 to 2008.

## Investment costs per MWP between 4 million EUR and 8 million EUR

The average investment cost per MWp of large-scale PV power plants in 2008 due to pvresources was about 6 million EUR. Investment costs according to data analyzed by pvresources increase almost linearly - for a 60 MW power plant an investment of approximately 360 million EUR is required. Please note that this are average values with regard to all technologies and mounting types used – for particular PV power plant average investment cost can vary from about 4 mio EUR up to 8 mio EUR per MWp, depends on technology used, mounting structures etc. The evaluation of investment costs presented in the annual report is based on detailed investment related data of about 220 PV power plants. Overall investment cost is slightly higher for tracking PV power plants (compared with power plant with fixed mounted arrays). Power plants constructed with thin film modules require an average investment cost of about 4 million EUR/MWp. Detailed investment costs of analysed power plants over the last five years (2004 – 2008) are presented in the pvresources report.

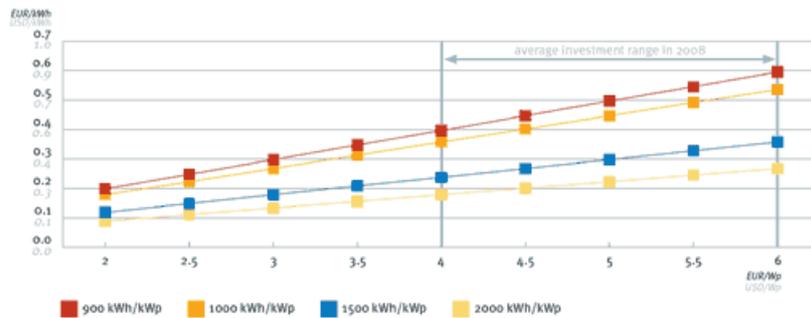


Investment costs (EUR/Wp and USD/Wp) for 220 analysed ground mounted power plants – sorted by technology (samples are sorted only by year and not by exact date of completion)

### Electricity price mainly depending on technology used and annual yield

Electricity price estimation is based on the investment data of PV power plants and on the predicted yield as announced by plant owners or plant planning/construction companies.

Electricity prices for systems with a planned 20 year lifetime with discount rate of 5 % and for typical annual yields of 900 kWh/kWp, 1000 kWh/kWp, 1500 kWh/kWp, and 2000 kWh/kWp are presented in the figure below. In this calculation annual maintenance costs representing 1% of the investment are considered. The yield range presented in the above mentioned figure covers (rough estimate) the typical annual yield achievable in European countries. 900 kWh/kWp can be attained for example in Germany using fixed mounted systems, while up to 1500 kWh/kWp are possible in southern Italy, Greece and southern Spain and about 2000 kWh/kWp in those same countries using two-axis tracking systems.



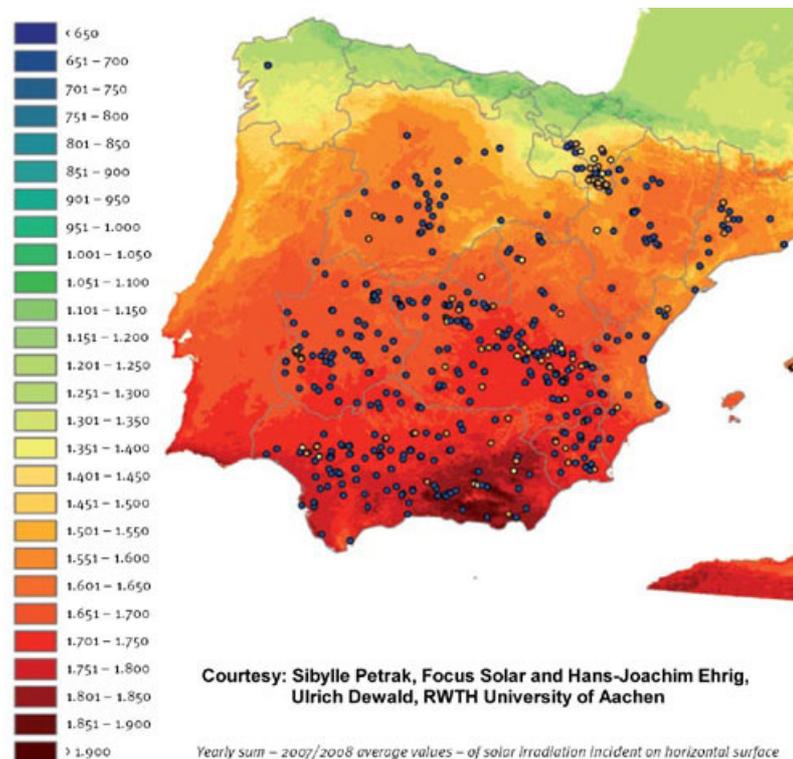
Sample calculation of electricity price (EUR/kWh and USD/kWh) for a 5 % discount rate for different yield rates.

Considering 20 years system life time, discount rates will range typically from 5 % to 8 %, considering above mentioned yields and typical maintenance costs, electricity price can vary between 0,19 EUR/kWh (investment of 4 EUR/kWh) up to 0,75 EUR/kWh (investment of 6 EUR/kWh) for example.

### Pvresources Annual Review 2008 Extended Edition

The complete pvresources report includes basic data such as annual and cumulative installed power output capacity; it also includes various statistical charts and geographic maps. Data is sorted by year of construction, region, country, etc. As much as possible technology and investment related data were analysed. Detailed data about the solar cell technology used, trackers, investment information, etc. is also included

for the largest markets. This report is the result of cooperation with the companies Focus Solar; the Department of Economic Geography, RWTH University of Aachen; Suravia, S.A. and the Solarserver web portal. It features some exclusive, never before published information like maps on various themes related to large-scale photovoltaic plants and basic economical calculations related to investments of large-scale photovoltaic systems. This is the first report that covers not only the full range of large-scale photovoltaic power plants and their historical progress over time (it offers a detailed overview of the last 15 years), but also includes basic economic data related to yield, installation price and price per kWh of solar electricity produced in large-scale PV power plants.



A sample map from the forthcoming pvresources Annual Review 2008 Extended Edition. Solar irradiation incident (kWh/m<sup>2</sup>).

Regardless of whether you are an engineer, market analyst, investor or customer – in this report you will find useful comprehensive information and statistical data about large-scale photovoltaic power plants available nowhere else, covering a wide range of their applications.

The pvresources “Annual Review 2008 Extended Edition” report will be available in June 2009 on CD at [pvresources.com](http://pvresources.com), [solarserver.de](http://solarserver.de) and [solarserver.com](http://solarserver.com).

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