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Energy Industry Guides

PV POWER PLANTS 2013

Industry Guide

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Cover images

Front
The Jännersdorf Solar Park in Brandenburg (Prignitz), which boasts a capacity of 40.5 MW, was completed in June 2012 and put into operation in accordance with the German Renewable Energy Sources Act (EEG).
Photo: Tom Baerwald/Parabel AG

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Central inverters in a large-scale PV installation
Photo: Regine Baeker/shotshop.com

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Photovoltaics' Innovative Forces

By Karl-Heinz Remmers,
CEO of Solarpraxis AG

Dear Readers,

If a British company in the automotive industry builds a five megawatt (MW) solar plant on its factory roofs in the North West of England, as happened recently, a large amount of solar power no longer flows into the grid. The plant capacity covers up to 40 percent of the company's energy needs. This way, that 40 percent can be used at a stable price regardless of market prices for electricity because it is produced and consumed on site.

Another example of how energy-intensive production facilities have made major headway when it comes to energy self-sufficiency can be found on the other side of the globe. In Tennessee, USA, a PV plant produces 9.5 MW of rated output on the premises of an automobile factory. When the manufacturing facility operates at full capacity, the solar power plant provides 12.5 percent of the electricity required. It can even meet the entire energy needs if production is ground to a halt.

These two projects show that more and more energy-intensive companies are now turning to the on-site production of solar power in the megawatt range to, at least in part, meet their energy needs. However, what happens if the electricity is to be consumed off site and several megawatts of power are to be integrated into the public grid as usual? After all, the continued success of renewable energy increases the risk of overloading the power grid because sun and wind provide fluctuating energy that does not follow consumption.

Storage systems are the solution. They are both an opportunity and a necessity. On one hand, they allow for a time gap between power production and consumption (which of course is also good for direct consumption); on the other hand, the energy revolution can only be successful if renewable energy storage systems can ease the burden on the public power grid in the long term.

However, large-scale storage for PV plants is not yet competitive, with the exception of pumped storage. Specific geographical conditions are needed for pumped storage, which can therefore only be implemented in a limited number of places and, even then, this significantly impacts the environment – decentralization is a different matter.

Although the technological tug of war has only just begun and it remains to be seen if we will combine mechanical, electrochemical or electrical storage with large-scale PV plants in the future, storage systems will no doubt transform the centralized grid structure into a decentralized one. Together with an intelligent energy management system, they pave the way for large-scale grid integration of photovoltaic power. Technology that is used in various applications from load balancing to cloud mitigation will play an important role in the near future. The inverter will become a flexible interface which takes over associated system management tasks.

Experts are still engaged in a zealous debate when it comes to weighing up the costs and benefits of storage technologies. Most concepts for large-scale PV plants have not yet emerged from the experimental stage. Small, privately-owned PV systems will be the first to see storage take hold, in favor of increased direct consumption. A look at current projects shows that storage for large-scale plants is still a marginal topic and a major challenge. That said, the industry is already waiting in the wings – and photovoltaics will once again prove how it is driving the energy revolution forward thanks to its innovative force.

Best regards,

Karl-Heinz Remmers

PV as a Power Player

By Dr. Winfried Hoffmann,
President of the European Photovoltaic Industry Association (EPIA)

Dear Readers,

PV is no longer a niche technology. It is rapidly becoming an important contributor to Europe's power system. As large-scale PV plants provide an ever-increasing share of the continent's electricity, stakeholders and policymakers need to consider some new challenges, including how to integrate variable electricity production into the grid.

While there is no denying that the PV industry has been navigating difficult waters over the past year or two, it is also true that the technology is holding steady on its course for competitiveness against other sources of electricity. The world's cumulative PV capacity surpassed an astounding 100 gigawatts (GW) in 2012 – a landmark few would have thought possible even five years ago. And in 2012, more than 30 GW of PV capacity were installed globally, nearly the same as in the record-setting year of 2011. In some regions (e.g. Germany, Italy) there is already today a high penetration of PV in the distribution grid. The associated challenges can be solved by providing grid services from the PV systems and sound adaptation of the future smart grid.

But as the saying goes: With great power comes great responsibility. The increasing share of PV electricity in Europe's power system is raising a series of important issues – mainly stemming from the variable nature of PV electricity generation. However, as shown in the recent EPIA report, "Connecting the Sun: Solar photovoltaics on the road to large-scale grid integration", PV is already providing solutions to these challenges.

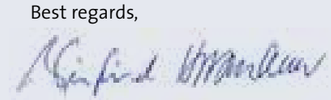
Without a doubt, large-scale PV plants remain an important driver of the technology's evolution into a mature and mainstream energy source. But it's clear the market is changing in important ways. Europe's dominance of PV in all segments is giving way to a more balanced – and, ultimately, sustainable – market with different regions around the world driving different segments.

Going forward, the utility-scale segment is expected to decline or at best stagnate in Europe even as it booms in the Americas and Asia including China and Japan. Under almost any scenario for the coming five years, the Asia-Pacific region should see the largest share of new utility-scale applications.

But the fact that the market for big PV power plants is changing does not diminish the importance of its role in meeting Europe's ambitious energy and environmental goals. PV can, together with wind, help provide up to 45 percent or Europe's electricity needs in 2030. With the right policies in place, even the utility-scale segment can grow in Europe over the medium to long term, especially in southern Europe.

People want solar power. Even the technology's harshest critics in the conventional energy sectors will ultimately have to agree that under all scenarios envisioned in the coming decades, solar PV will be a major part of Europe's (and the world's) electricity mix – with electricity gaining an increasing share in the global future secondary energy.

Best regards,



Dr. Winfried Hoffmann

The Industry

PHOTO: TOM BAERWALD/BELECTRIC TRADING GMBH

Heading for New Dimensions

Long-term investment with low risk

PHOTO: BELECTRIC TRADING GMBH

Ground-mounted photovoltaic power plant in Templin (Germany): With 1.5 million thin-film modules, 114 central inverters and a capacity of 128 MW, the power plant plays an important role in supplying the wider Berlin area with electricity.

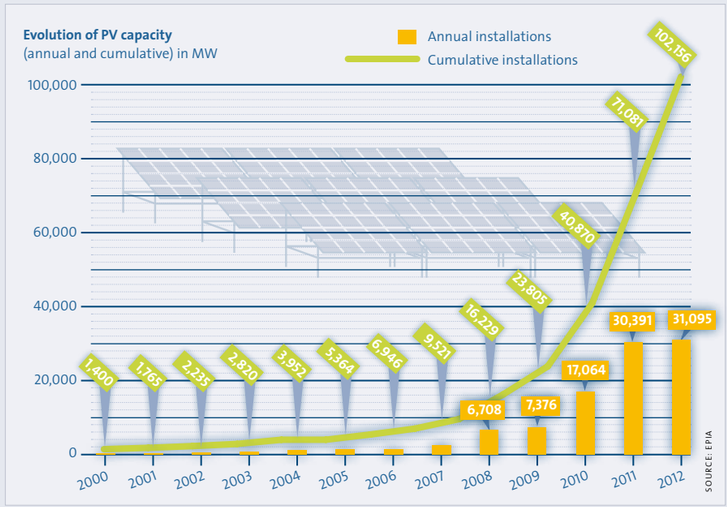


PHOTO: JUWI AG

The Lieberose Solar Park near Cottbus (Germany): Covering an area of 660,000 m², the current second largest solar park in the world boasts 900,000 thin-film modules and a capacity of 71 MW.

While ground-mounted photovoltaic systems have to date predominantly generated medium-scale outputs of between 500 kilowatts (kW) and 100 MW, they are now reaching dimensions similar to those of large-scale power plants. For example, a solar park with a rated output of 290 MW was connected to the grid in Arizona in 2012 and the world's largest solar power plant, which boasts an output of 579 MW, is expected to be fully operational by 2015. The outputs of photovoltaic power plants are thus achieving scales equal to those of conventional coal-fired power stations, and in Asia, there is even talk of gigawatt power plants, which have so far been the preserve of the nuclear industry.

According to data from the European Photovoltaic Industry Association (EPIA), 31.1 GW of solar power were connected to the grid in 2012, which amounts to slightly more than the previous year (2011: 30.4 GW). With the exception of Europe and Japan, where numerous small and medium-sized PV plants are also being installed, this rapid expansion of capacity is predominantly being achieved through large solar power stations with megawatt-scale outputs. In fall 2012, the cumulative capacity of all photovoltaic plants installed worldwide exceeded the 100 GW mark, and despite some countries reporting setbacks in market growth, the rapid increase in additional capacity added is set to continue worldwide throughout 2013 and 2014.

EPIA predicts that the utility-scale market (2.5 MW and above) could quadruple from 9 GW in 2012 to 37 GW in 2017, if adequate support mechanisms are accompanied by a strong political will to establish PV as a major power.

There are a variety of reasons for the increasing importance of large photovoltaic plants. Rising efficiencies, both in solar cells made from crystalline wafers and in thin-film modules, are juxtaposed with rapidly plummeting system prices. It is chiefly solar modules that have become noticeably cheaper.

Module prices are expected to stabilize during the course of 2013 as a result of existing overcapacities disappearing from the market. The price of other important components, such as inverters and substructures, is also falling, a development that is fuelling the worldwide boom in large-scale solar power plants and small roof-mounted systems alike. On the other end of the spectrum, the fuel costs of conventional power plants are increasing, causing power generation costs to rise with them. This is making the solar park market segment progressively more lucrative for financially strong investors – even in the face of tumbling feed-in tariffs.

Deciding factor economic viability

Project planning and management, installation and the operation of ever larger PV power plants present new challenges to planners, investors and bankers alike. The larger the plant, the more likely it is that the proposed solar plant's profitability, rather than the client's credit standing, will be the deciding factor that determines whether or not the bank will finance the project. The profitability of the installation plays a decisive role in terms of project financing, while the investor's credit standing hardly comes into question at all.

We must also bear in mind that countries such as Germany and Italy are slashing government incentives for solar power that are provided in the form of a legally guaranteed feed-in tariff. As a result, the photovoltaics power plant market is increasingly playing by the economic rules of the power generation market and it is no longer the level of the feed-in tariff but rather the levelized cost of electricity (LCOE) that decides whether or not investing in solar power plants will pay off. The LCOE is stated in either euros or US dollars per kilowatt hour (kWh) and takes into account the total cost of generating power, including investment costs for the plant itself, operating and maintenance costs, and other variable costs for the entire lifetime of the photovoltaic system.

At present, photovoltaics is obliged to compete with peak load power generation from gas power plants. Peak load occurs worldwide around midday when factories are working at full steam and the amount of power required for cooling is at its highest. This is when gas-fired and pumped-storage power plants are generally started up, as electricity prices are particularly high at this time of day. In Germany and several regions in the USA, up to 40 percent of the peak load power is provided by photovoltaics on some sunny days. At the European Energy Exchange in Leipzig, the falling procurement costs for solar power are striking, because its yield curve correlates closely to peak demand. Solar power curbs the cost of peak power and if the weather conditions cause a surplus of solar and wind power, this may even result in "negative" electricity prices being reached.

Solar power generation is already economically viable in southern countries such as Spain, Italy and Greece. Installation costs are falling steadily and, despite a lack of feed-in tariffs, investing in photovoltaics is becoming lucrative in many places – particularly in installations where grid parity has become tangibly close to being met or has even been exceeded. This trend was observed worldwide during 2012 and is likely to continue in 2013. By the end of 2012 it was possible to install a 770 kW solar generator for one million euros. Protecting such investments is of critical significance. Precise analysis and evaluation of all technical, financial, tax-related and legal details is therefore required to ensure the success of a solar project.

Speed matters

Size is not the only thing that counts, however – speed plays a big role, too: Power plants with large outputs of 100 MW and above can be planned and installed in a matter of months when using photovoltaics. No other technology is able to match this. Thanks to standardization and high quality levels, solar power plants are becoming ever more financially feasible and are yielding respectable returns – even with falling feed-in tariffs. In order to cover the worldwide electricity demand of around 12,000 GW with photovoltaics and other renewable energy sources over the coming years, the annual amount of newly installed solar power plants must reach around 300 GW. However, the markets are still far from achieving this target. In Germany alone, solar generators with a capacity of around 200 gigawatts peak (GWp) are required to ensure that – when working in combination with wind energy, hydropower and biomass – the power supply is fully covered by renewable sources.

PHOTO: TOM BAERWALD/BELECTRIC TRADING GMBH

With a rated output of 37.8 MWp, the large-scale solar power plant in Reckahn (Brandenburg, Germany), which has a surface area greater than 98 ha, prevents the production of more than 28,000 t of CO_2 each year.

PHOTO: TOM BAERWALD

In Lüptitz (Saxony, Germany), private individuals made investments in order to construct and operate a joint, citizen-funded solar power plant. The 4 MW installation was connected to the grid in September 2011.

Better integration into the power grids

Generating solar power locally requires restructuring the existing centralized power grid so that it contains decentralized facilities. Grid connection, especially in terms of large-scale ground-mounted solar power plants, presents a particular challenge, since the dramatic expansion of photovoltaics is increasingly creating bottlenecks in the power grids. If solar power plants are to succeed in making substantial contributions to the power supply, they must also play a greater role in maintaining grid stability. Technological progress in power electronics has resulted in solar inverters being able to feed reactive power as well as real power into the grids, freeing up additional grid capacity and easing expenditure on new, expensive power lines. Solar inverters are able to stabilize the grid because when combined with batteries, they can substitute the inertia of the rotating masses found in common power stations. According to plans made by the European Network of Transmission System Operators for Electricity (ENTSO-E), all large-scale solar power plants must be able to perform such a function from 2017.

Increasing attention is being paid to hybrid power plants, which generate both solar and wind power in close proximity to one another and are able to use the same grid feed-in point. Here, the costs of purchasing and developing the land are only incurred once, as are those for the medium-voltage switchgear (transformers, feed-in point). Solar power is generated throughout the day between sunrise and sunset, during which time it evens out the volatile feed-in curves of the wind turbines. In contrast, these turbines primarily produce energy in the evening, morning and overnight. Because both systems operate together at partial load for most of the time, better use is made of the feed-in point. Taken together, solar parks and wind power plants only exceed the maximum grid capacity locally available to them during very short and rarely occurring periods of the year, meaning that very little, if anything at all, needs to be spent on grid expansion.

With the success of renewable energy increasing the risk of overloading the grids – due to sun and wind providing fluctuating energy that does not always follow patterns of consumption – storage systems can be used to relieve the pressure on the public power grid in the long term.

It remains to be seen if mechanical, electrochemical or electrical energy storage will predominate in large-scale PV plants in the future. Coupled with an intelligent energy management system, storage systems will, in any case, pave the way for the large-scale integration of photovoltaic power into the grid. Inverters will serve as flexible interfaces, taking over associated system management tasks.

Photovoltaic power plants have also been proven to be extraordinarily capable of withstanding natural disasters. As Superstorm Sandy hit the highly populated east coast of the USA, the area's large-scale power plants lost their connection to the grid. However, while it took a considerable number of hours for the conventional large-scale power plants to be started up again, the solar parks on Long Island were immediately able to feed power into the grid once the storm had passed.

Rising demand

In the spring of 2012, the German government made drastic cuts to the feed-in tariff for large-scale power plants. From April 1, 2012, plants with outputs of between 1 and 10 MW received only 13.5 euro cents per kWh. Meanwhile, the feed-in tariff (for newly installed installations) has continued to sink monthly, meaning that by the end of 2013 it will only stand at around ten euro cents per kWh, and solar plants with a rated output of over 10 MW will receive no statutorily regulated remuneration whatsoever. While the latter may continue to be built, they must market the solar power they produce themselves. Countries such as Italy, France, Great Britain and Spain are following suit by supporting large-scale PV plants with statutorily regulated remuneration less and less. On the other hand, a growing number of communities and companies want to gain independence from the rising electricity prices charged by conventional suppliers. They can stabilize their power procurement costs by using large industrial roofs or communal areas to generate (their own) solar power.

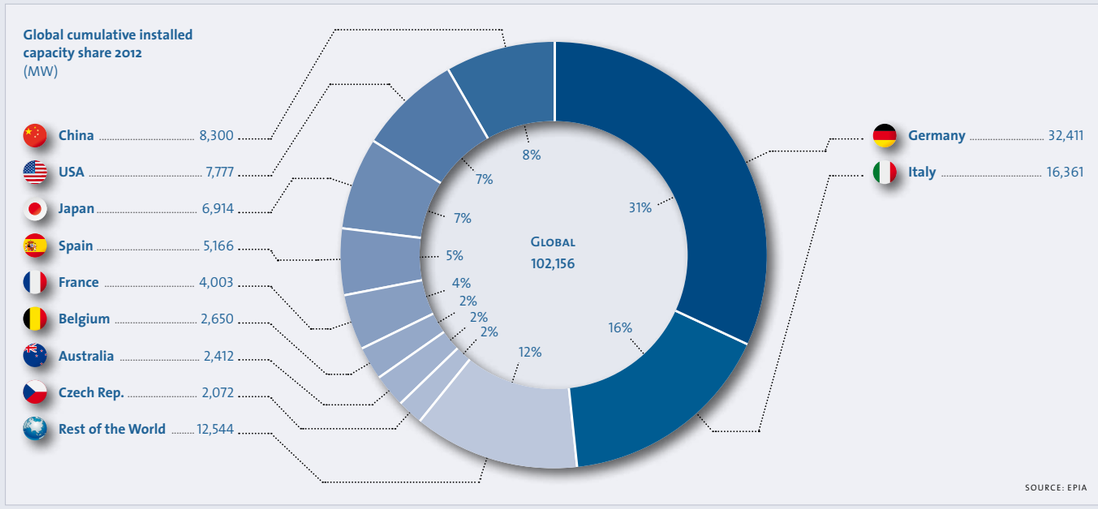
Even without any additional stimuli from the state, demand is growing – particularly in Asia and the USA. For example, economic mechanisms are already driving forward the expansion of photovoltaics in the USA, where PV power plants are financed using Power Purchase Agreements (PPA). In this system, solar power is sold to regional grid operators at a fixed price. In Canada, too, photovoltaics is increasingly becoming first choice for building new peak load power plants, and in China, Thailand and India, governments and major utility companies are currently inviting tenders for a range of new projects. In Africa and South America, solar power vies for precedence with power from distributed diesel engine power stations, meaning that rising fuel prices are giving solar power new economic momentum here, too – even without legally guaranteed feed-in tariffs.

In regions with high levels of insolation such as Spain, the Middle East and North Africa, the southern States of the USA, India and parts of China, modern solar generators are already able to produce electricity at a price lower than conventional sources (a phenomenon known as grid parity). Even in Germany, the feed-in tariffs for solar power were below the end consumer prices for power from the grid in 2012. Grid parity is also increasingly a matter of consideration for decision makers working on the power generation side. Of course, to be permanently competitive in this market, the costs will certainly have to drop a great deal further.

Top 15 markets 2012 worldwide

	COUNTRY	2012 NEWLY CONNECTED CAPACITY (MW)	2012 CUMULATIVE INSTALLED CAPACITY (MW)
1	Germany	7,604	32,411
2	China	5,000	8,300
3	Italy	3,438	16,361
4	USA	3,346	7,777
5	Japan	2,000	6,914
6	France	1,079	4,003
7	Australia	1,000	2,412
8	India	980	1,205
9	United Kingdom	952	1,829
10	Greece	912	1,536
11	Bulgaria	767	908
12	Belgium	599	2,650
13	Spain	276	5,166
14	Canada	268	765
15	Ukraine	182	373
	Rest of the World	2,692	9,546
	Total	31,095	102,156

SOURCE: EPIA



Market segments

In principle, three key photovoltaics market segments can be distinguished: "Residential PV" (capacity of a few kW) is where the investor is a private customer wanting to install solar technology on the roof of his house. Commercial users such as factory owners or public authorities form the "commercial PV" segment, where solar plants produce between 30 and several hundred kW. Major investment projects in the MW range are described as "utility-scale" plants. They are subject to the regulations on power plant construction.

Huge potential outside of Europe

PHOTO: ACTIV SOLAR GMBH

Solar park in Perovo (Ukraine) with a rated output of 100 MW. The additional 800 green jobs created during the seven-month construction period allowed the economy to be stimulated locally

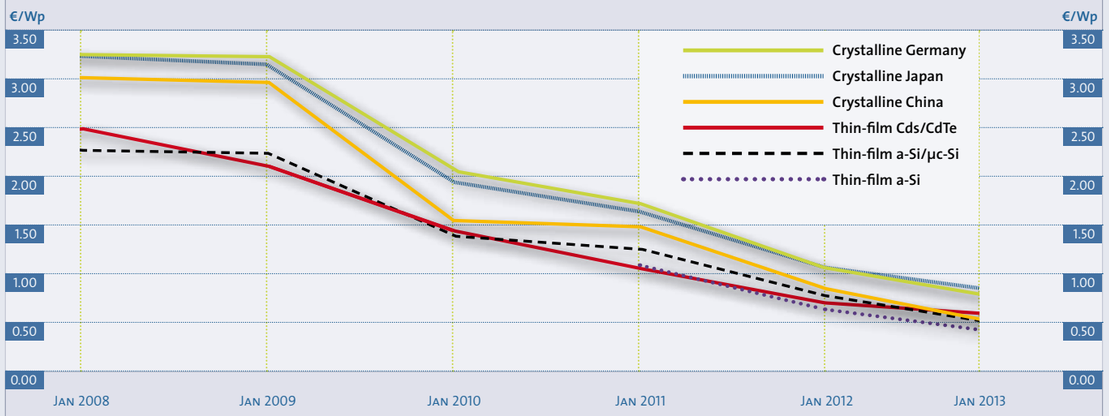
PHOTO: SIG SOLAR GMBH

PHOTO: AREVA GMBH

Left: 4 MW plant in Possidente (Italy). A general contractor was responsible for implementing the solar plant during the entire process chain.

Right: The Sabaranis solar park in the village of Saint Amadou (the department of Ariège, France) has a rated output of 8.5 MWp. 16 inverters feed solar power into the public grid via the plant's own medium-voltage transformers.

Module price trends* 2008 to 2013



*average offer prices on the international stock market

SOURCE: SOLARPRAXIS AG/SOLOGICO

The market's most important driving forces are the falling system costs of photovoltaics and the increasing price of electricity generated using conventional technologies. While solar module prices could stabilize in 2013, system costs are more likely to change. EPIA estimates that the price of PV systems belonging to the utility-scale sector (2.5 MW and above) will fall by a quarter within the next ten years, from 1.22 euros per watt (W) in 2012 to 0.92 euros per W in 2022.

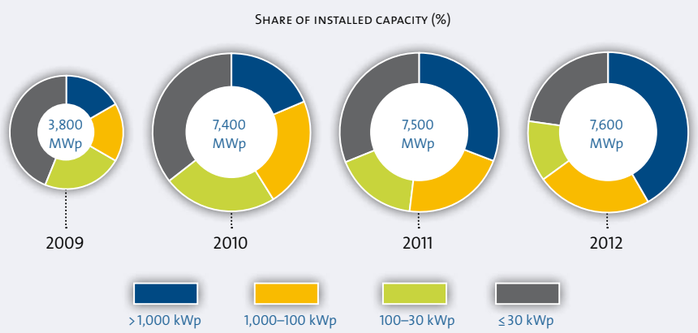
In 2012, the market for large solar farms with outputs over 1 MW developed rapidly worldwide, becoming the fastest growing sector within the solar market. While the European and Japanese markets are dominated by smaller roof-mounted installations, expansion in Asia, North America and other regions has almost exclusively stemmed from installations within the utility-scale sector.

According to figures from EPIA, 31.1 GW of new installations were added in 2012, with 17.2 GW in Europe. Europe's share is declining: In 2011, 22.4 GW were installed on the continent (30.4 GW globally). Analysts at NPD Solarbuzz predict that emerging markets, such as China, North America and India, will also grow further in 2013. In 2012, they were responsible for around a third of new PV capacity installed worldwide.

Europe

In terms of global cumulative installed capacity, Europe still leads the way with 17.2 GW connected to the grid in 2012. This represents 55 percent of the world's annual PV capacity. The European photovoltaics market is dominated by four countries: Italy, Germany, France and United Kingdom. Together they accounted for 75 percent of the European market in 2012. The most important single market was Germany, which installed 7.6 GW of new capacity (7.5 GW in 2011).

Germany: annual installed capacity 2012 (MWp)



SOURCE: BUNDESNETZAGENTUR/SOLARPRAXIS AG (FIGURES ARE ROUNDED)

A new set of rules governing feed-in tariffs have applied in **Germany** since April 1, 2012, lowering remuneration to 13.5 euro cents per kWh for ground-mounted solar installations with outputs of between 1 and 10 MW. Additionally, the feed-in tariff for new installations is falling further each month in line with the current rate at which new capacity is being installed, and plants with capacities greater than 10 MW no longer receive any remuneration whatsoever, with additional restrictions applying in the case of neighboring power plants, for example. It is therefore expected that in the future the construction of new solar power plants with MW-scale outputs in Germany shall exclusively follow the cost-effective investment model of directly marketing solar power currently in use in the USA.

It has been estimated that the German market shall reach a capacity of between 4 and 5 GW by the end of 2013. It remains uncertain as to what extent power plants in the MW range will contribute to the newly installed capacities over the years to come. In 2012, systems greater than 2.5 MW contributed around 40 percent of the annual installed capacity in Germany.

However, since PV systems with outputs of 10 MW and more are no longer supported by a feed-in tariff, this amount is likely to fall.

In **Italy**, the fact that the money made available by the fifth Conto Energia was used up prematurely by the start of 2012 meant that the amount of new photovoltaic capacity installed in the country fell from 9.5 GW in 2011 to 3.4 GW in 2012. Here, political debates have prompted a drastic reduction in feed-in tariffs and in the middle of 2012, the government in Rome decided not to support any further ground-mounted solar parks.

In addition, all solar generators with outputs greater than 12 kW must be entered into a plant registry in the future. No restrictions are to be made on the installation of smaller systems. However, feed-in tariffs are being cut significantly: 3 kW installations will receive 23.7 euro cents, roof-mounted installations with an output of 200 kW 19.9 euro cents per kWh, and ground-mounted installations 16.1 euro cents per kWh. Experts anticipate that expansion in Italy will almost exclusively ensue from roof-mounted installations, though on roofs with sufficient surface areas, these are able to achieve outputs of several MW. The amount of new capacity installed is likely to amount to between 1.5 and 2 GW in 2013 and the years to follow.

According to figures from EPIA, **France** connected around 1.8 GW of solar power to the grid in 2012, more than 2011 with 1.1 GW. A feed-in tariff only exists for installations with a rated capacity of up to 100 kW. Calls for tenders are used to fund large projects. The government in Paris plans to limit the annual installation of new photovoltaic systems to 500 MW. Interestingly however, France had to import solar and wind power from Germany at the start of 2012 and 2013 due to the cold winter. French homes are predominately heated using electricity, meaning that increasing electricity costs and a lack of capacity within the country made these imports necessary.

The performance of the year in 2012 came from **Great Britain**, which installed 925 MW of new capacity (2011: 813 MW). 912 MW was newly constructed in Greece, owing to the fact that the country's sunny

Left: Spain: solar park in Viana. With a capacity of around 9 MW, the park is able to supply more than 2,500 households with electricity.

Right: Thanks to the highest levels of irradiance throughout Greec, nine solar parks on the island of Crete generate around 1.2 MW of clean electricity each year.

Below: Konya, a city in the Central Anatolia Region of Turkey, boasts the country's first grid-connected photovoltaic power plant. The system generates around 300,000 kWh annually.

PHOTO: ALEO SOLAR DEUTSCHLAND

PHOTO: CONERGY

PHOTO: IBC SOLAR AG

climate allows photovoltaics to act as an alternative to the increasing price of power generated from coal. Meanwhile, Bulgaria, another country with a high level of insolation, installed 767 MW. Despite its comparatively small size, Belgium installed 599 MW of capacity, mainly in the form of "small" roof-mounted systems.

Spain has completely stopped feed-in tariffs for solar power produced by new installations, meaning large-scale solar power plants are now only possible via the open market. High levels of insolation and reliable solar radiation conditions, combined with a continuous fall in the price of PV components, have opened up this market segment, breathing new life into the Spanish solar market (2012: 200 MW). For example, a solar farm with an output of 250 MW, which is to be installed in the province of Cáceres by 2015, will be solely refinanced by the commercial sale of solar power. Work at the site, which is in a region with very high levels of insolation, is due to begin in 2013. The solar farm will cover an area of 750 hectares and is expected to cost around 250 million euros. It will achieve an annual yield in the region of 400 million kWh.

Turkey has also introduced feed-in tariffs for solar power, as well as increased remuneration for using PV components manufactured within the country. However, the authorities require an extensive amount of supporting evidence before granting these incentives. High levels of insolation of up to 1,500 kWh per square meter in south and south-east Turkey also create favorable conditions for photovoltaics, and the Turkish market is expected to undergo a significant upturn. In order to minimize currency risk for foreign investors, the feed-in tariffs below are quoted in US cents. The government in Ankara pays 13.3 US cents (around 10 euro cents) for every kWh of solar power generated. Added to this are incentives for using components manufactured domestically, which amount to as much as 6.2 US cents. While plants with a rated output of less than 500 kW do not require any approval, licenses are required for larger power plants, and the addition of new capacity up to 2013 was limited to 600 MW. Moreover, individual plants may not exceed capacities of 50 MW. The electricity demand in Turkey is set to double by 2020, meaning that shortages in the power supply are expected from 2017. 200 MW of new capacity are expected to be installed in 2013, with these figures set to rise to 600 MW in 2014 and 1.2 GW in 2015. In contrast, only 2 MW of capacity were installed in the country in 2012.

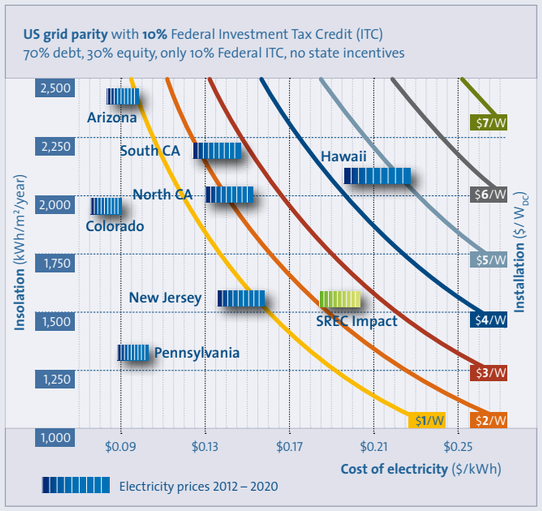
The **Balkan states** are yet to play a significant role in the large-scale installation market. Falling system prices could, however, prompt moderate growth in Bulgaria (2012: 767 MW) and Slovenia (117 MW). Both countries have introduced feed-in tariffs which are significantly higher than those in Germany and Italy. In Ukraine, large-scale solar power plants with capacities of 100 MW were installed, predominantly in the southern regions around Odessa and along the Black Sea coastline.

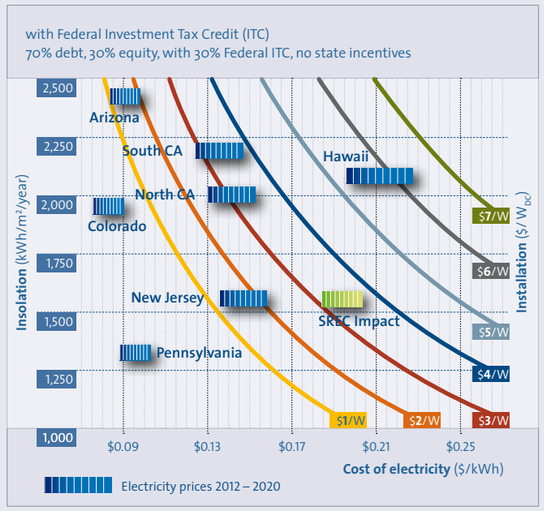
The future course of development in Poland is rather uncertain, as although the government in Warsaw is working on a law to promote renewable energy that also intends to include a feed-in tariff for solar power, this shall not be passed before the government's 2013 summer break. As a result of the weak grid, connecting large-scale power plants is expected to prove particularly problematic.

It can generally be assumed that the market for MW-scale installations in Europe will become increasingly difficult. However, the direct marketing of solar power modeled on the USA's Purchase Power agreements is paving the way towards independence from government subsidies. The first of Germany's solar power market sectors (in particular roof-mounted systems) are expected to fall below grid parity in 2013/2014. In Italy and Spain, this milestone has already been reached for ground-mounted photovoltaic systems. However, large-scale photovoltaic installations do not compete with the electricity price paid by end customers (private households and/or companies), but rather with the market price of peak load power.

With 250 MW (AC) of solar power connected to the electricity grid, the Agua Caliente Solar Project, which is located 65 miles east of the city of Yuma, Arizona (USA), is one of the world's largest operational PV power plants.

PHOTO: FIRST SOLAR





SOURCE: NAVIGANT, EIA

North America

Electricity from solar power has already achieved grid parity in southwest USA and Hawaii. Colossal solar parks capable of delivering a total capacity of up to 750 MW are being planned or are already under construction in California, Arizona, New Mexico and Nevada. In addition to the high prices of peak load power, Investment Tax Credit (ITC) incentives of up to 30 percent are stimulating growth. However, these are set to fall to ten percent by 2017. Some states launched new incentive programs in 2012 to support the installation of small roof-mounted installations, while the building of large-scale solar power plants continues to follow the regulations governing power plant construction. The announcement that the major American investor Warren Buffett was purchasing two solar power plants in California caused a stir in the fall of 2012. The investment, which amounted to around 2.5 billion US dollars (1.8 billion euros), saw Buffett acquiring the Antelope Valley Solar 1 and 2 power plants in California. The two power plants, which boast a cumulative capacity of 579 MW, are expected to be connected to the grid by the end of 2015.

The graphs illustrate the time when grid parity is reached as a function of the installation costs: The placement of the federal states is explained by their levels of insolation and the (expected) development of electricity prices from 2012 to 2018.

Placement either on or to the right of the graphs indicates when grid parity will be reached, for example in New Jersey, installation costs of 1 US dollars per W and an ITC of ten percent will give grid parity in 2018 – without SREC (Solar Renewable Energy Certificates or Credits). SREC are awarded in some federal states. They commit electricity producers to incorporating increasing amounts of power from renewable energy sources into their power plant mix (Renewable Portfolio Standard, RPS). The aim is to step up solar investment in order to lower both emissions and the consumption of fossil and nuclear fuels. The Credits or Certificates are used to calculate the targets that are actually achieved. Power plant operators are able to refinance their investment by selling SREC on the market in addition to the solar power they generate. This creates investment incentives that are similar to the CO_2 certificates in the European Union.

Tax allowances, or ITC, represent another approach. They allow investors to claim part of the investment for tax relief purposes and offset it against their tax liabilities. ITC vary according to state (e.g. ten percent or 30 percent).

The effects of both incentive systems can be seen in the supply price for solar power, which is negotiated between the operator of the solar farm and the regional grid operator (often also the region's energy utility). The pricing regime is usually fixed for a period of 10 years and is based on the supply contract, the PPA.

In the hot regions of North America, electricity is most expensive around midday, when air conditioning and cooling systems in homes, supermarkets, factories and public utility companies are working at full capacity. Power suppliers usually start up gas power plants to cover these peak periods. Solar power produces its highest yields during the middle of the day, however, meaning its yield curve corresponds perfectly to demand. In the USA, large solar farms are almost exclusively financed by ten-year supply agreements for solar power known as PPA. The average price, which varies according to regional conditions, is roughly 20 US cents per kWh and guarantees a profitable investment.

EPIA puts the amount of newly installed capacity at 3.3 GW in 2012, compared to 1.9 MW in 2011. Analysts estimate that the market in the USA will grow by 4 GW during 2013 and predict an increase of 30 percent each year until 2016.

The Sarnia Solar Farm in Ontario (Canada) produces 80 MW of solar electricity annually. A portion of the site is also home to a 100-acre tallgrass prairie restoration project that creates new habitats while increasing soil stability and water quality.

PHOTO: FIRST SOLAR

Saudi Arabia: The ground-mounted photovoltaic plant with a peak output of 3.5 MW is located in Riyadh in the grounds of the KAPSARC (King Abdullah Petroleum Studies and Research Center), the largest oil research center in the world.

PHOTO: PHOENIX SOLAR AG

New solar parks are also being planned south of the border between the USA and Mexico with the aim of exporting solar power to the USA. Feed-in tariffs have either recently been launched or are due to be introduced in a few Caribbean countries. Puerto Rico, for example, intends to cover a third of its electricity demand of 3 GW with solar power by 2020.

In Canada, the province of Ontario, in particular, has seen a high number of new installations. However, the Green Energy Act introduced in 2009 expired in January 2012, and the government has announced plans to cut the feed-in tariffs by 20 percent. According to data from EPIA, around 268 MW of solar power were installed in Canada in 2012 (2011: 497 MW).

The Middle East

Photovoltaic markets are still in their infancy in the Horn of Africa, the Persian Gulf and the Middle East. Saudi Arabia's level of insolation is roughly 2,200 kWh per square meter, which is approximately double the average level in the area between the North Sea and the Mediterranean Sea. The Saudian Arabian government has announced plans to cover a tenth of its energy requirements with solar energy by 2020 and it hopes to install around 5 GW of solar power. Investors have so far pledged around three billion US dollars for photovoltaic generators. There are currently several medium-sized solar farms in Saudi Arabia with outputs of up to 10 MW. Larger solar farms are to be funded through auctions and calls for tenders, and it is hoped that this will lead to between 1 and 2.2 GW being installed by 2015.

A large number of investments are also being made in photovoltaic installations in Qatar and Jordan. A solar power plant with an output of 200 MW is being planned in Oman and will be installed over the next few years. A 1,000 MW solar farm is also set to be installed in Dubai. The Mohammed bin Rashid Al Maktoum Solar Park, which is currently estimated to cost 2.4 billion euros, will cover an area of 48 square kilometers. The first step is to construct a 10 MW photovoltaic power plant, which will be connected to the grid in 2013.

PHOTO: DUPONT APOLLO LIMITED/ CHINA EVERBRIGHT INTERNATIONAL LIMITED

The 1.3 MW PV power plant in Guangming New District, Shenzhen (China) covers about 23,000 square feet of roof space, and is constructed of 13,000 amorphous silicon thin-film modules.

A 20 MW PV system on an industrial rooftop in Guangdong: In southern China's province of Guangdong, abundant industrial rooftops provide the basis for the "Thousand Factories, Thousand Megawatts" program.

PHOTO: SKY SOLAR

India: The 600 MW Gujarat Solar Park (close to the Rann of Kutch at the border with Pakistan) is an innovative concept designed by the state government to promote solar installations in which the government allocated developed land to the project developers with the entire infrastructure intact.

PHOTO: SEDA MALAYSIA

China

China may be the most important market of the future for photovoltaic power plants, but it is also the most challenging. According to data from EPIA and Solarbuzz, the Chinese photovoltaic market grew by 5 GW in 2012, meaning that the solar power plant capacity in the Middle Kingdom more than doubled in one fell swoop. Since the beginning of 2012, Beijing will pay one renminbi per kWh solar power (approximately 11 euro cents). The Chinese aim to install around 5 GW of capacity every year until 2015. Large solar farms make up the majority of new photovoltaic installations in China. While merely a few demonstration projects were installed between 2009 and 2011, the Chinese market is now on the verge of enormous growth. The majority of utility-scale plants are being installed in Western China, Inner Mongolia and Tibet. Here, the solar power plants belong to the state and are regarded as infrastructure projects, which are constructed through calls for tender.

The insufficient state of the power grid is the greatest hindrance to development. In the province of Qinghai, where roughly half of China's large solar farms are located, around 1 GW of capacity was newly installed in 2012, but only 50 percent of it was connected to the grid in good time. Above all, there are not enough transformers for the 380 kilovolt (kV) transmission lines. In Tibet, the construction of a 220 kV line to connect additional solar power plants has been delayed.

PHOTO: CONERGY DEUTSCHLAND GMBH

The solar park in the Thai city of Ayutthaya, which is located around 70 km from the capital Bangkok, has a capacity of 3 MW.

India and Thailand

India is ideal for solar power, in spite of the high investment costs of 12 to 13 percent which inhibit the market. In India, a great deal of electricity is produced off-grid with diesel-driven generators. According to data from EPIA, the LCOE for solar power is between 14 and 16 euro cents, making it competitive in comparison to diesel power, particularly in light of the country enjoying around 300 days of sunshine every year. Especially in the western and southern parts of the sub-continent, insolation is very high and evenly spread. By the end of 2012, 1.206 MW of solar capacity had been installed, with around 1 GW newly installed capacity in 2012. The states of Gujarat, Rajasthan and Madhya Pradesh in particular put out large-scale power plants to tender.

The state of Jharkhand aims to install around 500 MW by 2017 and 2.2 GW by 2020. In West Bengal, where at the start of 2012 only one power station with an output of 2 MW was in operation, the aim is to install around 500 MW by 2020. Additionally, Chhattisgarh has set itself the target of installing 1 GW by 2017.

A demonstration project of a smart grid in the village of Rokkasho (Japan), incorporating the world's first wind and photovoltaic plant that stores its power in bespoke large-scale batteries.

PHOTO: TOYOTA

Cagayan suburbs (the Philippines): The PV plant with a total output of 1 MW uses 6,480 polycrystalline silicon modules that produce around 1,300,000 kWh of electricity per year.

PHOTO: DPA PICTURE-ALLIANCE GMBH

PV production plant in Malaysia

PHOTO: Q-CELLS INTERNATIONAL GMBH

Meanwhile, Thailand aims to increase its solar capacity by approximately 500 MW by 2020 in order to achieve its target of covering 20 percent of its electricity requirements with solar power. This market is driven by PPA. The state puts power plants out to tender, fixing the purchase price of solar power at 19 euro cents per kWh for ten years, but in 2012, the price fell to 15.2 euro cents. By mid-2011, solar power plants with a total capacity of around 3.4 GW had been proposed in Thailand but the grid is the major hindrance to progress here as well. The amount of newly installed capacity amounted to around 210 MW in 2012.

Japan, Malaysia and the Philippines

Following the nuclear reactor disaster in Fukushima, Japan has rejoined the world's largest solar nations. In 2012 2 GW of new solar capacity were installed (2012: around 1.3 GW). The Japanese market is similar to Germany's, however, in that it is dominated by small roof-mounted installations. The on-site consumption of solar power is playing an increasingly significant role, as Japan has the highest electricity prices worldwide. All of its 45 nuclear power stations are not connected to the grid anymore, production capacities of conventional systems there have reached their limit. In the Greater Tokyo Area, industrial companies must reduce their electricity demand by around 15 percent or are forced to generate the same amount using their own solar power

New, lucrative feed-in tariffs have been in effect since July 2012 which are boosting the market. Small private plants, on the other hand, are no longer receiving any remuneration whatsoever because on-site consumption allows them to pay for themselves. Ten Japanese energy suppliers are planning to make considerable investments in utility-scale solar farms. Feed-in tariffs have been introduced for both roof and ground-mounted installations of 10 kW and above. The tariffs are graded to ensure that large solar parks and B2B installations with large solar outputs will chiefly be developed. Remuneration is fixed for the solar power from each installation for ten years, after which it is phased out in several stages.

A feed-in tariff for solar power was introduced in Malaysia as early as at the end of 2011. Installations with outputs of more than 10 MW can expect to receive around 20 euro cents per kWh. However, solar farms with a total capacity of over 30 MW receive no subsidies whatsoever. A feed-in tariff amounting to around 60 euro cents per kWh has also been paid in the Philippines since the end of 2011. The country has been struggling with rising electricity prices, and discussions on whether to lower the tariff to approximately 30 euro cents are ongoing.

The Mallee Solar Park in the Australian state of Victoria has a capacity of 180 MW and uses CdTe modules.

PHOTO: TRUENERGY

Australia

Like the southwest USA, Australia requires a lot of electricity for air conditioning and cooling systems during the summer. In 2011, electricity during the peak midday period was sometimes offered at record prices of 10,000 Australian dollars per megawatt hour (MWh). The standard price is between 35 and 50 dollars. The use of photovoltaics is therefore highly attractive in Australia, since solar installations generate most electricity during the middle of the day. The extreme peak prices yield considerable profits. According to figures from EPIA, capacity installed in 2012 alone amounted to 1 GW, a slight growth compared to 2011 (837 MW). Increasing numbers of large-scale installations are set to be constructed in Australia to stabilize energy supply and lower electricity prices during the summer.

Solar installation on the Cape Verde Islands: The continent of Africa is beginning to exploit its enormous potential for generating renewable energy.

PHOTO: STIFTUNG WORLD FUTURE COUNCIL

Africa and South America

As of yet, the photovoltaic markets in Africa and South America have hardly got off the ground. In 2011 und 2012, Kenya and South Africa became the first African countries to install large plants. During the course of 2012, initial plans were drawn up to construct several solar power plants each with capacities greater than 70 MW. Thanks to its relatively well developed infrastructure, stable financial system and advanced grid, South Africa has been awarded the accolade of being the sunny continent's market leader. Here, the World Bank plays a considerable role in funding the power plants.

In South America, further drops in the price of solar technology should stimulate significant market growth. Increasing attention is being paid to solar power plants in Chile and Brazil in particular. The sunny, dry plateaus of the Andes are particularly ideal for solar power plants. The first pilot power plant with an output of 1.4 MW, which supplies a nearby copper mine, was installed in northern Chile in 2012.

In addition to providing millions of people in South America and Africa with power for the first time, photovoltaic power plants on these continents also make it possible to provide precious drinking water at a low cost, support communication networks and store vital medicine and food in air-conditioned storage areas.

State of play: May 2013

Having completed the first phase in just ten months, the power plant in La Huayca (Chile) aims to increase its 1.4 MW output to 30 MW by 2013.

PHOTO: SOLARPRAXIS AG/BECKY BEETZ

Striving for increased efficiency

PHOTO: TOM BAERWALD

Crystalline modules (below) and thin-film modules (right): Owing to the relatively high efficiency of crystalline modules, a smaller installation area is needed per unit of output compared with thin-film modules.

PHOTO: TOM BAERWALD

Today, thin-film modules are mainly used in large installations.

PHOTO: TOM BAERWALD

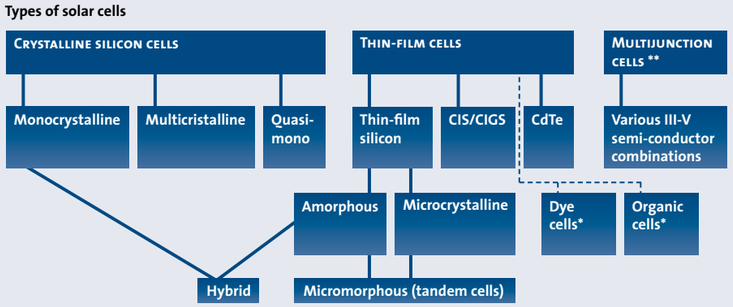
Until just a few years ago, PV plants were chiefly built from components that were often only available in limited quantities and PV modules were lacking in particular. This is changing as production capacities are undergoing dramatic expansion. Today, solar power plants are planned, installed and financed as system solutions, and at the end of this chain comes the price per kWh of solar electricity, which competes with that of other technologies. During the first stage of the market launch, the solar energy price per kWh must be lower than the feed-in tariff in order to ensure that the PV power plant is profitable. During the second stage of market penetration, it is sufficient for the price to be less than that of conventional power generated by coal-fired or nuclear power plants. Return on investment is therefore determined by the efficiency of the entire system, from individual modules to inverters and grid feed-in.

Crystalline silicon or thin-film

Business in MW-scale PV power plants is dominated by crystalline silicon and cadmium telluride. Crystalline silicon solar cells have many advantages: Commercial mono- and polycrystalline silicon modules now achieve 14 to just over 20 percent efficiency. Owing to the relatively high efficiency of these modules, less installation area is needed per unit of output, which also means that fewer mounting frames and cables are required. New "cast-mono" wafers achieve similarly high efficiencies to monocrystalline solar cells thanks to the particularly cheap polycrystalline silicon wafers employed.

Innovative processes, such as the string-ribbon process, may reduce manufacturing costs further. A thin ribbon of silicon is pulled from a melting crucible between two wires. This technique facilitates the production of ultra-thin wafers just 135 micrometers (µm) thick and eliminates the heavy material losses that ensue from sawing conventional silicon wafers, which are 180 µm thick. Tandem cells that combine crystalline wafers with amorphous silicon coatings achieve extremely high efficiencies with the wafers being exceptionally thin. Novel cells with selective emitters and rear-side contacts are only between 100 and 120 µm thick. Bifacial cells that are also able to absorb sunlight on the rear sides of modules and thereby boast yields of between 25 and 30 percent higher than comparable standard modules have also been on the market since 2012.

Types of solar cells



* Research, experimental stage / ** Space travel, concentrator system

As thin-film modules are significantly less efficient than crystalline silicon modules, they need to cover up to 30 percent more surface area than crystalline silicon modules to achieve the same output. This entails increased costs for installation, support frames and cabling. However, thanks to intensive research and development the efficiency of thin-film modules is currently improving at a faster rate than that of crystalline silicon modules. The efficiency of research modules fitted with cadmium telluride cells has now increased to more than 18 percent, while that of cells made from copper-indium semiconductors has risen to more than 17 percent. If these efficiency values are also attained in commercial modules, the fact that thin-film solar modules require a larger surface area will no longer have so such a bearing.

Since it is now possible to manufacture thin-film solar modules in large numbers, the costs of doing so have plummeted. In terms of price per unit of output, thin-film modules now cost the same as crystalline modules. However, the manufacturing costs (and therefore the prices) of solar modules with crystalline silicon solar cells have recently fallen at a greater rate than those of thin-film solar modules, resulting in the current market share of thin-film technologies declining somewhat.

As a general rule, large-scale PV plants equipped with thin-film modules can produce power just as cheaply as those constructed using crystalline modules. The lower manufacturing costs may therefore compensate for the increased outlay incurred for installation.

In addition, thin-film modules perform favorably in diffuse light conditions and at high temperatures. They utilize weak light more efficiently and, compared to crystalline silicon, their output is not so badly impaired when they heat up. This makes them significantly more suitable for the hot climate of the sunbelt, semi-desert and desert regions.

Colossal factories for producing thin-film modules with silicon technology or with compound semiconductors of copper indium gallium selenide are currently under construction. Production capacities for inexpensive cadmium telluride (CdTe) modules have experienced the strongest growth. Both CIGs and CdTe technologies have made the successful leap to bankability, demonstrating their reliability in large solar farms. In spite of this, 2011 and 2012 saw the market share of thin-film technology recede, as the decline in prices for crystalline modules coupled with their high efficiencies led to a resurgence of crystalline silicon technology in large-scale plant construc-

CELL MATERIAL	MODULE EFFICIENCY		SURFACE AREA NEED FOR 1 KWP
Monocrystalline silicon	14-20%	5–8 m²	
Polycrystalline silicon	11–15%	7–9 m²	
Micromorphous tandem cell (a-Si/µc-Si)	8–10%	10–12 m²	
Thin-film – copper-indium/gallium-sulfur/diselenide (CI/GS/Se)	10–12%	8–10 m²	
Thin-film – cadmium telluride (CdTe)	9–11%	9–11 m²	
Amorphous silicon (a-Si)	5–8%	13–20 m²	

Cells made from different materials have different efficiencies. PV array surface area depends on the type of cell used.

Process steps in quality control

Quality control is not only applicable to modules, but to the entire installation:

Planning phase
- advice when selecting components
- review of installation design
- shading analysis, grid connection approval, yield assessment
- help in obtaining construction permits
- review of quotations
- assessment of economic efficiency

Construction phase
- inspection and testing of received goods
- inspection of components
- measurement of module output, insulation testing
- inspection of construction progress
- performance testing and measurements for approvals

Operational phase
- visual installation inspection
- thermography
- sample measurements
- insulation testing
- defect detection, analysis and assessment of damage

Monitoring
- technical management and operation
- performance monitoring
- yield analysis and preparation of operational reports

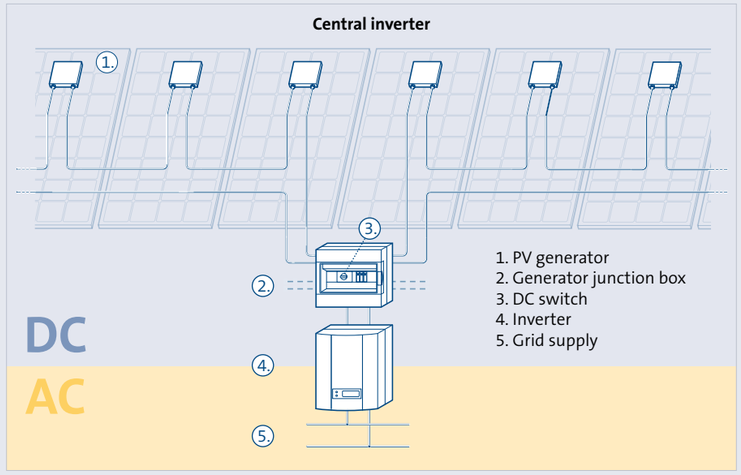
Measuring the temperature coefficient

PHOTO: TOM BAERWALD/SOLARPRAXIS AG

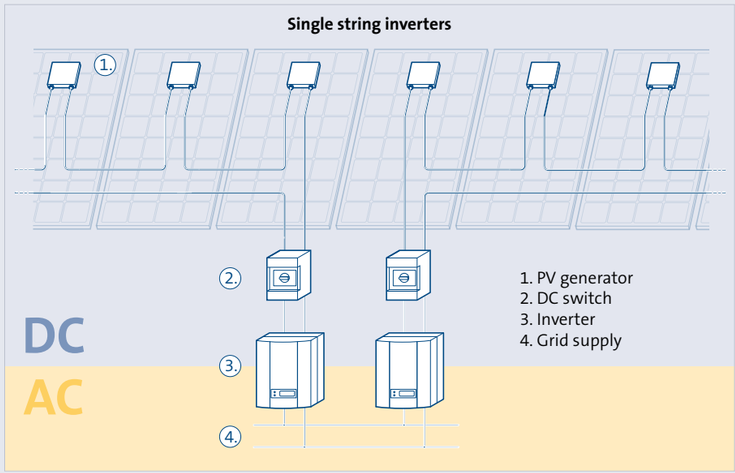
PHOTO: HÜTTINGER ELEKTRONIK GMBH + CO. KG

PHOTO: TOM BAERWALD

Quality assurance at all stages from the factory to the construction site guarantees long-term yield stability and operational safety.



The PV array consists of several strings of series connected modules. The whole of the installation is served by a single central inverter.



Single-string inverters take a single string of series-connected modules. Each string has its own inverter.

tion. Nevertheless, the new factories being built across the world are virtually exclusively intended for the production of thin-film modules. Significantly smaller investment funds are required here than for silicon cell and module manufacturing technology, so it can be expected that a growing proportion of thin-film modules will be found in large-scale plant business over the medium term.

The temperature coefficient

The temperature coefficient indicates the percentage by which a module's output will drop as its temperature increases. With crystalline silicon modules, output falls by around 0.5 percent for every degree of increase in temperature. This value is just 0.25 percent with thin-film modules. To calculate this, the output under standard test conditions at a module temperature of 25 °C is used as a starting point. To illustrate, a solar power plant with monocrystalline solar cells and a rated output of 1,000 kW will only generate 800 kW, even under maximum insolation, if the solar cells' temperature rises by 40 kelvin (K) to 65 °C. In contrast, a power plant with the same rated output but equipped with CdTe solar modules will yield 900 kW.

Quality assurance from factory to construction site

The long-term yield stability, operational safety and thus investment security of a photovoltaic system are primarily dependent on the longevity and reliability of the modules and system technology used. These qualities are examined in complex test procedures as laid down in industry standards or technical guidelines. test certificates and additional quality marks provide evidence that a module meets the necessary requirements.

Independent institutes certify solar modules using test samples supplied by the manufacturers. The PV+Test (www.pvtest.de) introduced by Solarpraxis AG and the German Technical Inspection Association (TÜV Rheinland), on the other hand, buys samples covertly so that manufacturers are not able to preselect which items are tested. Increasing importance is being attached to testing for potential induced degradation (PID), electroluminescence cell and module inspection and thermography, as these analyses reveal weak points in production and allow flaws to be detected faster.

In addition to these types of approval tests, spot checks at photovoltaic power plants ensure that the manufacturer data corresponds to the components that are actually delivered. Such quality testing can involve different levels of complexity and cost, from visual checks and performance measurements to electroluminescence and thermal imaging. The purpose of testing is always to safeguard the anticipated long-term yield and minimize the risks of technical failure. Drones are increasingly being employed to fly over large-scale, multi-MW plants in order to gather thermal images of the module arrays. Solar farms with outputs in excess of 10 MW can be inspected using helicopters.

Extra audit

When buying a large quantity of modules, it is always sensible to place the products delivered, their manufacturers, as well as the components and materials used under closer scrutiny. An audit helps to validate the results of various module tests and estimate the risks of a project. As certificates from different test institutes may vary considerably, results are more meaningful if manufacturers subject their products and components to more stringent testing, and not simply to that specified in the standards. There is no such thing as absolute security, but reasonable assessments can be made. Checklists can also prove useful in analyzing the risks of a product.

Standardization

At present, manufacturers supply products with highly specific features in an attempt to make them as distinct as possible from those of their competitors. If the wide variety of solar modules could be reduced through standardization, it would open up enormous scope to bring down the costs associated with systems technology. This is why large project developers are changing their strategy to offer only standardized power plant units comprising just one specific module type and one particular plant design (substructure and string connection). These modular units allow the solar plant output to be scaled up rapidly with the greatest of ease.

Inverters

Solar generators are a combination of solar modules connected in series and in parallel: Depending on the voltage of a given solar module, up to 30 of them may be connected in series to form a string, so the electrical voltages of the individual modules will add up. Connecting 20 to 30 modules in series produces a string with a system voltage (direct current, DC) of up to 1,000 volts (V).

In very large solar farms, it can sometimes make sense to increase the DC voltage to 1,500 V, as this allows for lower current in the DC cabling. Consequently, smaller cable sizes can be used, which in turn significantly lowers the cost of cabling. At the same time, thermal losses are reduced owing to the low DC current. On the other hand, the junction boxes must be equipped with fuses certified for these voltages, which are more expensive than those for lower voltages. The inverters, too, must be approved for the higher DC input voltages, and thus require power electronics that are designed for such purposes. Suitable transistors are even more expensive. The major advantage of having a higher system voltage is the option it provides to combine solar arrays with wind energy systems. Such hybrid power plants take up the same area and feed power into the grid via a joint switching station.

Inverters regulate solar voltage and solar power such that the solar generator will furnish the maximum possible output, even with constant fluctuations in temperature and insolation. They convert the direct current generated by photovoltaic systems into alternating current that can be fed into the grid. While smaller systems feed single-phase power into the low-voltage grid (grid voltage of 400 V), larger solar power plants with outputs of 100 kW and above feed three-phase current into either the low-voltage or medium-voltage grid, which can have a voltage of between 20 and 50 kV, depending on the national grid standard in a given country.

Not all inverters are suitable for every type of module (depending on MPP voltage window, whether or not a transformer is present and whether or not the DC circuit is grounded). It should there-

Central inverter housing: Several strings are connected to one inverter.

PHOTO: TOM BAERWALD/SKYTRON ENERGY GMBH

String inverter: The electricity is fed into the grid by several, independent inverters.

PHOTO: TOM BAERWALD

tracker (i.e. each string) with its own inverter. Assessments of technical and economic viability will determine which option will best improve a given system. When performing such assessments, the impact of an inverter and its efficiency on plant yield is given the same consideration as how the choice of system design will affect the system and installation costs. Ultimately, preference will ideally be given to the system with the lowest levelized cost of electricity, allowing for the plant to be operated in the most profitable way possible.

Module Level Power Management

Of late, module level power management (MLPM) solutions have increasingly gained precedence. Known as power optimizers, they are called upon to increase the output of individual modules. They enable maximum power point tracking (MPPT) for each module and minimize mismatches arising from production tolerances or shading. Micro inverters, also known as module inverters, take things a step further. They convert direct current from the module directly into grid-ready alternating current. This eliminates losses and avoids a whole series of additional technical problems which can result from complex DC cabling in large inverter systems.

An enhanced version of the power optimizer was recently launched onto the market as module maximizer. This device not only tracks the MPP, it also records the output data of a module at any given moment and sends this to the central monitoring system. This allows drops in the performance of individual modules to be detected straight away.

Central inverters versus string inverters

In a central inverter design, several strings are connected to one inverter with an output of up to 2 MW. The device is usually made up of several output units of say 500 kW. These units operate in a master/slave configuration where one is responsible for controlling the system (master) and switches on the inverter's additional output units (slaves) as insolation and generator output dictate.

As a result, inverter operation under partial load – unfavorable owing to the low conversion efficiencies achieved – becomes less frequent, which increases the system yield by several percentage points. The inverter units regularly exchange roles (master/slave) in order to balance out the operating times of the device parts and increase service life. In a string inverter system, just a few strings are connected to an inverter with a lower output. In the case of solar generators, where strings track the sun on individual tracking units, it can prove beneficial to equip each

European and Californian efficiency

Inverters operate less efficiently if low insolation means that they can only feed in a portion of their rated output, as is the case, for example, in the morning or afternoon, or in cloudy conditions – operation under partial load thus results in lower efficiency. Weighted efficiency enables a comparison to be drawn between the efficiency of different devices. European and Californian weighted efficiencies are two commonly used comparison standards that correspond to the differing insolation conditions in Central Europe (weaker, more diffuse insolation) and California (stronger, more direct insolation).

Good inverters operate with peak efficiencies of almost 99 percent. 98 percent is taken as a guideline for solar parks with outputs of over 1 MW. The amount of power consumed by the inverters themselves is an important factor which largely determines the feed-in period over the course of the day.

Above all, high efficiency and high plant availability mean higher yields: If the average inverter efficiency or annual availability can be increased by around three percent, a 1 MW solar park will generate approximately 86,000 US dollars of additional revenue within ten years.

The capacity of inverters should be adequately proportioned to allow regional peaks in insolation to be fully exploited without the devices becoming overloaded. It has become established that the STC rated output of solar modules should correspond to the AC rated output of inverters. Here, too, it is important to carefully plan the optimum technical and economic solution. Recent findings based on insolation readings taken at short intervals provide clues as to how additional yields can be harvested.

Efficiencies

Efficiencies calculated under laboratory conditions for different outputs (partial load efficiencies), which can be employed in various formulae, are required to make the calculations. The following formula is used for European efficiency (in regions with total annual solar irradiance of around 1,000 kWh/m² on the horizontal plane):

$$\eta EUR = 0.03\,\eta 5\% + 0.06\,\eta 10\% + 0.13\,\eta 20\% + 0.1\,\eta 30\% + 0.48\,\eta 50\% + 0.2\,\eta 100\%$$

For regions with high solar radiation – approximately 1,200 kWh/m² annual global irradiance upon a horizontal surface as in southern Europe – Californian efficiency gives more appropriate results. In accordance with the different conditions of radiation, the formula is:

$$\eta CEC = 0.04\,\eta 10\% + 0.05\,\eta 20\% + 0.12\,\eta 30\% + 0.21\,\eta 50\% + 0.53\,\eta 75\% + 0.05\,\eta 100\%$$

PHOTO: TOM BAERWALD

Increasing conductibility has resulted in an ever greater number of PV plants feeding their power into the medium- and high-voltage grids.

PHOTO: TOM BAERWALD/BELECTRIC TRADING GMBH

The key to the grid

The greater the output a solar farm feeds into the grid, the more important protection against grid failure becomes. The directive on medium voltage grid feed, which came into force in Germany, takes this requirement into account. If grid stability is threatened, the grid operator can either disconnect a plant or use it to stabilize the grid. This may include maintaining grid voltage and grid frequency, balancing real and reactive power in the grid and phase shifting at the feed-in point. Inverters must also be able to ride through short grid interruptions of 200 milliseconds without shutting down the plant (fault ride through). This capability allows them to support the grid, meaning that large-scale PV plants have great potential for stabilizing power grids. New central inverter models are even capable of stabilizing the grid with reactive power and freeing up grid capacity during the night. To do so, they take real power from the grid and then feed it back into the grid at an efficiency of 99 percent, though when this happens a dramatic phase shift is seen in the current and voltage, which manifests itself as a high level of reactive power. In the future, large inverters fitted with batteries will take charge of grid management in the initial critical milliseconds of instability. These solar inverters are able to stabilize the grid as they can substitute the inertia of the rotating masses found in large-scale fossil fuel power plants by using energy reserves from storage devices. This also results in energy utilities' conventional regulating power plants, which are also known as must-run units, becoming redundant.

Permanent monitoring of plant operation is essential for investors and operators alike, as it permits faults and failures to be recognized and rectified quickly, keeping yield losses to a minimum. Automatic operation monitoring and error diagnosis systems, which can either be integrated into inverters or installed separately, send alerts to operators via e-mail, text message, smart phone or cell phone and identify potential causes of error.

Grid feed-in guidelines

In the US, IEEE standard 1547 (voltage and frequency tolerance) applies to grid feed-in. There, inverters must also be able to identify when the subgrid is shut down. If power generation and power consumption balance one another out in this subgrid, a photovoltaic plant may continue to work independently – the grid will therefore remain live. In the event of "islanding", as this is called, a solar installation's inverter must therefore disconnect it from the grid. In Spain, the technical connection requirements must be regulated by contract between plant operators and grid operators (Art. 16 real Decreto 661/2007).

The economic and technical requirements for feeding solar electricity into the utility grid vary across the European Union, and even within member states. In Germany, the Renewable Energy Sources Act (EEG) provides a legal and economic framework, while the Medium Voltage Directive of the German Association of Energy and Water Industries (BDEW) lays down technical specifications. In fact, it must be possible for grid operators to control all the inverters in a solar park centrally. The BDEW Directive came into force in Germany 2011, and the Low Voltage Directive, containing special requirements on feeding into the low voltage grid, was introduced soon afterwards. Inverter manufacturers must provide certificates to demonstrate that their devices meet the new guidelines, and

PHOTO: TOM BAERWALD/PARABEL AG

PHOTO: TOM BAERWALD

Left: Fixing modules to the ground

Right: Aluminum mounting frames

PHOTO: TOM BAERWALD/SOLARPRAXIS AG

Dual-axis tracking system

PHOTO: TOM BAERWALD/YOUNICOS

Battery park belonging to a storage system developer: Storage systems capable of storing large quantities of energy for minutes or even hours at most are needed to drive forward the energy transition.

plant certificates must be issued following the installation of solar parks to confirm that their interaction with the power grid is appropriate and has been simulated.

Since July 2011, large-scale solar plants in Germany must be issued with a certificate proving their compliance with the technical specifications of feed-in management before they can be connected to the grid. The certification process is conducted by independent test institutes. In mid-2012, these test institutes were not numerous enough to process the backlog of applications. Therefore, transitional provisions were implemented until the end of 2012.

Foundation and anchoring

Solar parks should reliably generate electricity for at least 20 years. They are generally built on open land, such as former military sites, landfill sites, former mining fields or hitherto unutilized fallow land. Planning starts with a survey of the relief, solidity and the quality of the ground. Local wind and snow loads must also be taken into account when designing a photovoltaic plant.

Just like bridges, large-scale solar installations are vulnerable to wind-induced vibrations, though frameless modules exhibit different elastic properties to their framed counterparts. The simplest and least expensive types of foundation are ones that use piles driven into the earth. Alternatively, piles are also available that are screwed into the ground (screw pile foundations). Concrete foundations made from either ready-mixed or in-situ concrete provide a further alternative for applications such as tracking systems or those where the piles cannot be driven into the ground.

The modules are supported by systems made of wood, aluminum or steel. Wooden structures are comparably light but will warp in the course of 20 years. They must be waterproofed and should not come into direct contact with the soil. Aluminum is also an extremely light material. Systems made of this are easy to install and hardly corrode, but the price of aluminum fluctuates greatly. Furthermore, owing to the thermal properties of aluminum, heat and frost cause greater stresses in the structure. While steel substructures are more cost-effective, steel is not resistant to corrosion and is therefore unsuitable for some locations.

The mounting system must be capable of supporting the solar modules securely for a long period of time. Mounting a free-standing PV power plant is frequently easier than many other types of installation, as the construction area is more easily accessible than, say, a slanted roof. A big disadvantage of free-standing plants, however, is that they lack a truss to which to screw the assembly system. This is why anchoring the mounting frame safely into the ground is a factor which should be given adequate consideration, as it will need to keep the equipment stable for decades.

Tracking systems

Depending on their location, crystalline silicon modules can furnish up to 35 percent higher yields if they are able to follow the path of the sun mounted on trackers with one or two axes. Nevertheless, the higher investment costs and additional maintenance required are more likely to pay off in southern regions which receive a high proportion of direct insolation. In northern areas of Central Europe, financing this additional expenditure is becoming less and less worthwhile given falling module prices and higher maintenance costs.

Single axis trackers rotate PV arrays so that they follow the sun's daily path from east to west. Dual axis (hemispheric) systems also tilt on a vertical axis to follow the sun's movement.

The use of trackers entails considerable additional preparation work on the foundations; the ground must also be sufficiently stable. Furthermore, the surface area required for tracking systems is larger than that for non-tracking PV installations as, to avoid shading, trackers must be positioned at a sufficient distance from each other.

Cabling

Losses due to cabling are often underestimated. If the plant is badly planned, total energy losses in copper cables can add up – anything over one percent is unacceptable. To avoid high losses, the cable cross section must be relatively wide, while cable lengths should be as short as possible. During installation and operation of the PV plant, the plug connectors on the solar module cables must be checked to ensure that they are water tight and that the connections are not prone to fault voltage or short circuits.

Cables should not be exposed to direct solar radiation, so should be laid in shaded areas. This is because every degree of temperature increase in the copper material increases electrical resistance and multiplies losses as a result. What is more, sunlight (UV light in particular) can degrade the cable insulation material.

Lightning and overvoltage

Large ground-mounted PV plants always need their own protection system against lightning and overvoltage. Overvoltage can be caused by indirect lightening strikes and the associated electromagnetic induction in cable loops. According to TÜV Rheinland, in Germany almost 50 percent of all damage to PV plants is caused by overvoltage. Protection against direct strikes (direct strike lightning protection) or coupling as a result of strikes elsewhere in the grid (indirect strike lightning protection) must be taken into consideration during the initial stages of planning. Shutdown systems should also be integrated that allow the PV system to be swiftly disconnected from the grid in the event of fault voltages or fires.

Storage systems for solar power

Storage systems for PV power plants are just beginning to be competitive and it remains to be seen if mechanical, electrochemical or electrical energy storage will predominate in large-scale PV plants in the future.

While in 2012, lead-acid and lithium-ion batteries were only initially supplied for small-scale systems to optimize on-site consumption in private households, the first large-scale storage systems with a storage capacity of 500 kWh came onto the market in the second half of the year. In cases where the solar output must be regulated by grid operators, these systems allow the solar yield of a 1 MW power plant to be buffered for 30 minutes.

Synthetic methane (power to gas) is opening up a promising new path for technological development that will allow solar power to be stored on a major scale. The methane, which is generated from surpluses produced by the solar power plant, is known as wind gas or solar fuel. Once grid capacity becomes available again, methane can be converted into electricity in traditional gas turbines and fed into the grid. It is also used to generate peak load power.

Operation and maintenance

In addition to costs of the technology itself, the cost of operation and maintenance is another important factor to consider. These costs do not figure in construction of the installation, but can add up quite considerably over the service life of a solar power plant. For each kWh of solar power generated, between one and ten euro cents fall to the costs incurred during the 20- to 25-year operation of a plant. This large spread is owed to the wide range of potential costs: For example, these can include wear caused by extreme weather or vandalism. Expenditure is also incurred for monitoring plant safety and protection against theft. In the case of off-grid systems, battery costs are the real killer. Currently, investors can expect to pay around 10,000 to 14,000 euros for operation and maintenance on top of the costs for the technical system.

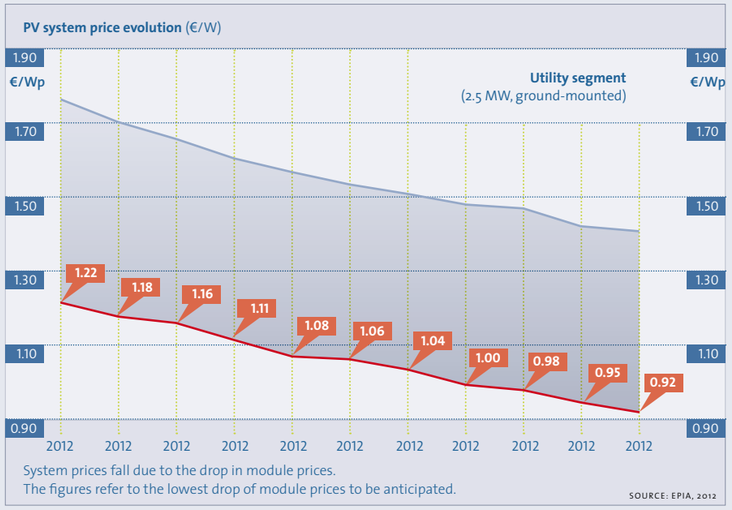
Low risk of default

PHOTO: EUROPEAN ENERGY EXCHANGE AG

The European Energy Exchange AG (EEX) in Leipzig (Germany) is one of Europe's leading trading centers for energy and energy-related products. On some days, up to 50 percent of the power traded on the spot market comes from renewable sources.

SOLARPRAXIS AG/ANDREAS SCHLEGEL

Technical due diligence: Independent engineers scrutinize the technical plant design.



System prices fall due to the drop in module prices.
The figures refer to the lowest drop of module prices to be anticipated.

SOURCE: EPIA, 2012

Until 2009, manufacturing and sales of technical components were the focus of solar business. For this reason, photovoltaic systems were valued first and foremost according to the system costs per kW of peak power. Now, however, photovoltaics is gaining an ever larger presence in the energy industry, and must therefore begin to gauge itself by the cost price per kWh. This not only includes the system costs, but also every bit of expenditure on realizing the solar project, the operating costs and financing.

Today, trade centers increasingly on projects, financing and exploitation rights, which makes photovoltaics attractive for the finance industry. Financing models taken from classic manufacturing industries are directing a significant flow of money into the solar industry. These include trading in turnkey projects, project rights and other forms of participation in companies that operate solar power plants – right through to the purchase and sale of entire power plants.

Banks provide financing in various ways. They either grant project loans via their house bank, meaning that the full risk will be shown on that bank's books, or they form syndicates to spread the risk exposure. Private capital is also being used more and more to fund solar projects. Club deals are common, where several banks pool a loan together as part of a skeleton agreement, with each of them on different terms. One of the banks coordinates the syndicate and acts as a contact with the client (borrower). However, with this model, the time between application and approval is longer meaning that investment costs are higher.

Thin-film plants are at the bottom end of the scale in terms of investment costs, while monocrystalline silicon parks with tracking systems are at the upper end. New module technologies (thin-film silicon, CIs or CIGs) are now also increasingly being classed as creditworthy, particularly if they are used in projects that mix them with proven technologies such as crystalline modules.

Opportunities for financing

Financing stands or falls with the actual annual solar power yield fed into the grid. Usually, banks expect a return on project investment of at least eight to nine percent. Private investors take between four and five percent if they conclude long-term deals where the degree of risk is low. The strong market for large-scale plants that prevailed at times in Spain (2008), Germany (between 2010 and 2012) and Italy (2011) often created unrealistic expectations of the returns that solar power was able to yield. The eurozone crisis and the withdrawal of state subsidization are therefore forcing photovoltaics to take a more realistic view of things – and enabling it to exploit its long-term advantages more successfully. Ever more investors are recognizing the fact that the technology has matured and the risk of default is low. The investment, and thus the prices it can achieve on the power market, is not linked to the uncertainties of the oil market. And the sun supplies its energy for free, which gives photovoltaics a fundamental advantage.

The benefit gained from minimal financial risk should not be underestimated, especially with large solar farms. These can be installed in small, modular units and financed, refinanced and traded in stages. This valuable aspect of photovoltaics means that it could soon drive out solar thermal power generation. Photovoltaics is being used more and more to create new power plant capacity, particularly in sun-rich countries of more southerly climes, where the hunger for energy grows day by day and where technology capable of grid-connected and stand-alone power generation is sought.

Thanks to the expansion of the production capacities of modules and inverters across the globe, there are practically no further production-related bottlenecks that could limit the growth of photovoltaics as an industry, and solar parks in particular. From now on, area and capital will be the critical factors. One consequence of this is that many module manufacturers also operate as developers of large solar parks, as technology is usually bought directly from producers in this business segment.

Levelized Cost of Energy (LCOE)

Before we are able to assess the competitiveness of photovoltaic power compared to conventional energy sources, consideration must be given to the LCOE, which determines precisely what costs are incurred when generating solar power. The LCOE is stated in either euros or US dollars per kWh and takes into account the total cost of generating power, including investment costs for the plant itself, operating and maintenance costs, and other variable costs for the entire lifetime of the photovoltaic system.

According to the report titled "Solar Photovoltaics Competing in the Energy Sector" published in September 2012 by EPIA, the cost of capital – expressed as the weighted average cost of capital (WACC) – is a key factor in the LCOE. The report states that the cost of capital has a greater impact on the LCOE than module prices, insolation at the site and plant lifetime.

According to EPIA, the costs of grid expansion by solar generators must also be quantified in the future. The same of course applies to fossil fuel and nuclear power plants which, to date, have only taken into account power generation costs. Among other reasons, the fact that using photovoltaics no longer involves any fuel costs means that the costs of distributing power and operating the grid are increasingly reflected in the calculation of electricity prices. Equally important are the cost-lowering effects of solar technology brought about by intelligent inverters, battery storage systems and on-site consumption.

No money without security

Loans are never granted without security. Examples of securities include the transfer of ownership of the PV plant, the transfer of rights from project contracts (delivery contracts, operating and maintenance contracts, contracts of use and occupation for the site, insurance contracts), encumbrances, pledging of the operator's account or pledging of shares in the business. In the past, project financing was sometimes too tight,

RES-LEGAL

The free RES-LEGAL database provides an overview of the manifold subsidization models in Europe as well as the stipulations and guidelines on grid connection. It contains all important legal regulations on subsidies and the feed-in of power from renewable sources. The collection of models for remuneration, tax incentives and certificates as well as grid access comprises all the EU 27 member states, the EFTA countries and some EU accession countries.

www.res-legal.eu

PHOTO: TOM BAERWALD

In 2012, systems with outputs greater than 2.5 MW contributed around 40 percent of Germany's annual installed capacity.

which led to non-performing loans. For this reason, banks often set requirements for the content of project contracts, or place stricter demands on the use of cash flow (reduced profit distribution). In addition, they require the quality of the installation to be inspected by external experts (technical due diligence). It is not uncommon for two independent yield reports to be requested.

Due diligence

A due diligence assessment serves to analyze the strengths and weaknesses of a project, as well as to evaluate its risks and estimate its economic value. The analysis particularly focuses on technical and material defects, legal and financial risks, and circumstances that stand in the way of a project being realized or being profitable. If risks are detected, this could lead to contractual allowances being made in the form of price reductions or guarantees – or in extreme cases, could trigger the abandonment of negotiations.

Assessment may, for instance, follow these four steps:

Legal due diligence
Legal experts check the legal basis of a project from purchase or rental of property to feeding in. Checks are made on the application to the utility as well as on the operating, maintenance and insurance contracts. Experienced project developers use standardized templates to exclude major risks.

Tax due diligence
This step examines the tax aspects of a project, such as corporation income tax, trade tax and income tax, value added tax, tax on profits, real property tax and land transfer tax, as well as taxes incurred during operation. Such an analysis includes tax incentives and depreciations and is carried out by independent consultants.

Technical due diligence
Independent engineers scrutinize the technical plant design. This includes: system planning (yield forecast, plant layout, inclination and alignment of modules, ground survey, distance from feed-in point, number of feed-in points, grid capacity), specification and selection of components, tenders and order placement, installation, technical quality management and building quality management, operational monitoring and safety, manufacturers' and installers' guarantees and warranties, creditworthiness of suppliers, theft and vandalism protection (fencing, closed circuit television) and the costs of maintenance and land management (for example mowing and pruning).

Financial due diligence
The last phase before a loan is granted concerns financial aspects: required investments (capex), costs for the property and yields from any future sale, Expected solar yield, costs for operation and maintenance (opex), liquidity reserves, insurance, costs for dismantling and recycling the plant after the end of its service life. The cash flow, taxes and debt services are used as a basis for evaluating profitability, which is the deciding factor in granting loans.

New business segment: power plant operation

To date, solar power plant project developers have commonly also assumed responsibility for maintaining and operating plants on behalf of investors. However, for the duration of the warranty period, a conflict of interests arises that is typically settled at a disadvantage to the investor. As a result, the fields of planning and operating large-scale power plants are increasingly going their separate ways, not least because ever more attention is being paid to expenditure on operation and maintenance (O&M) in a bid to limit the overall costs of investment.

Market forces in the energy sector

In Germany, many other EU countries, and in several others besides, solar electricity is sold to grid operators at a statutorily guaranteed feed-in tariff. During the first half of 2012, these feed-in tariffs were dramatically reduced, and in some cases stopped altogether, particularly for large-scale power plants.

The market for large solar power stations is therefore likely to mature within a short space of time. The era of statutorily guaranteed feed-in tariffs will soon be dead, and the dawn will rise on that of directly marketed photovoltaic power. the solar industry has reached this stage within just a few years. Throughout 2012 and 2013, solar power plants are likely to be subject to compensatory pricing before they finally become governed by the free interplay of market forces in the energy sector.

In many countries, expansion quotas are capping growth. Examples of this can be seen in Spain and Italy, where total spending on feed-in remuneration is limited to six million euros per year. In a different model, the German government is making all further development of feed-in tariffs dependent on an annual expansion corridor of between 2.5 and 3.5 GW, and intends to stop supporting solar power plants once a total capacity of 52 GW is reached. If feed-in tariffs were to disappear completely in the near future, however, the state would have virtually no grounds for capping photovoltaic expansion.

Incentives outside Europe

The picture outside of the EU is also heterogeneous. India is considering a feed-in law with guaranteed remuneration. China intends to designate large areas for solar power plants with capacities of several GW, though so far has only introduced uniform feed-in tariffs for small-scale installations. There, projects are controlled exclusively by the state and put out to tender through auctions.

Tax incentives play an important role in the USA (ITC), and can reach up to 30 percent. These sums can be directly offset against tax liabilities, and if no tax is due, the ITC are paid out to investors as negative tax. In addition, some states pay out for every kWh fed into the grid, while others offer tax bonuses and subsidies. PPA are the preferred business model for large-scale solar power plants. As part of these agreements, the solar power is sold to one energy utility or one large customer for ten or 15 years.

The project tenders commonly invited at auctions in many Asian, Arab and some European countries basically work on a similar financing model, only the price is decided during the auction. It is not uncommon for lengthy negotiations to ensue afterwards due to investments being only barely covered.

Little is likely to change in this practice in China, as the country has no private energy utilities. In countries such as India and Thailand, however, an economic mindset will increasingly win through and spur the markets on.

New feed-in tariff in Germany

In 2012, the German parliament voted in favor of drastically lowering the tariffs again. There are four power classes now: small rooftop systems with outputs up to 10 kW, larger roof-mounted installations with outputs between 10 and 40 kW, plants with outputs up to 1 MW and systems installed on roofs or on the ground between 1 and 10 MW.

The remuneration for solar power fed into the grid is set to fall each month in accordance with market development. While small plants with capacities of up to 10 kW and MW-scale power plants are remunerated in full, only 90 percent of the solar yield generated by power plants with the two medium-scale power output classes is set to be remunerated from January 1, 2014. Meanwhile, installations with capacities greater than 10 MW will no longer receive any statutorily regulated remuneration whatsoever but may continue to be constructed. The adjustments to the feed-in tariffs are being made by the German Federal Network Agency, whose website (www.bundesnetzagentur.de) lists the current rates of remuneration.

In the future, the outputs of all ground-mounted photovoltaic systems within a two-kilometer radius will be added together. If they are found to have a cumulative capacity of over 10 MW, these sub-generators will no longer receive remuneration, even if they belong to different owners. This rule is set to apply for an interim period of two years. In addition, the concept of commissioning a solar plant under the Renewable Energy Sources Act (EEG) established to guarantee the feed-in tariff paid in a particular month, has been reformulated, now stating that it is no longer possible to put modules of a photovoltaic system not equipped with an inverter into operation. However, the connection to the grid will continue to have no impact on the feed-in tariff a system receives.

Project Planning

Ensuring feasibilty

PHOTO: TOM BAERWALD/BELECTRIC TRADING GMBH

During operation, comprehensive monitoring and short reaction times in the event of failures result in a short payback period.

Good and thorough preparation by experienced planners can make or break a large solar park project. Owing to the size of the project, neglecting small points may soon lead to large quantities of money being lost. Careful planning does not only concern the assessment of yields and capacity or building permits. Other significant factors that determine the success of a project include on-site support, grid access inspection and certification of the feed-in management system.

PHOTO: TOM BAERWALD/BELECTRIC

The greater the level at which photovoltaic capacity is expanded, the more important it is for grid feed-in to be controlled precisely, especially in terms of large-scale solar parks.

Performance ratio

The ratio of actually generated power to the theoretical yield in a certain location is decribed by the performance ratio (PR). It serves as a measure of plant efficiency for evaluating different plants in different locations Top priority is being given to optimizing a plant's PR when operating in profitable conditions. Excellent PR values amount to between 80 and 83 percent (for crystalline silicon solar modules) or between 82 and 85 percent (for thin-film solar modules).

Based on the values for a 1 MW PV plant in the south of the USA (PPA: 0.2 US dollars/kWh, specific yield: 1,800 Wh/Wpeak, performance ratio 80 percent), an increase of ten percentage points in PR will earn an additional 396,000 US dollars annually.

Right: Monitoring devices are another way of monitoring and analyzing the various inverters within a plant.

Below: The inverters' design has a considerable influence on the plant's profitability.

PHOTO: TOM BAERWALD/LEBHERZ

PHOTO: TOM BAERWALD/BELECTRIC TRADING GMBH

Comparable calculations can be made for Germany. For instance, a PV power plant with a peak output of 1 MW, connected to the grid at the beginning of 2010 with a PR of 75 percent, would produce 863 MWh of electricity each year. Increasing the PR by ten percentage points to 82.5 percent by optimizing the system components would represent a total of 949 MWh. At a remuneration tariff of 13.5 euro cents per kWh, this would yield increased profits totaling 232,200 euros.

Expert opinion

Planning always starts with a survey to help determine what the solar yield, the foundations, the best modules, inverters and mounting technology will be. If the installation is planned on a former military or brownfield site, extensive preparatory work is needed to remove any ammunition or hazardous substances that may be present. Ensuring that the land is safe has top priority. Yields from the PV plant must be able to cover the purchase price or the rent for the land.

Certification of feed-in management systems

Before a solar farm can be connected to the grid, the future operators or project developers must submit a certificate issued by an authorized, independent test institute. This confirms that the plant technology complies with all technical specifications and grid-feed management guidelines issued by the German Association of Energy and Water Industries (BDEW). Other important documents must also be submitted, the installation must be simulated and an expert report must be commissioned. The whole procedure lasts several weeks.

Grid authorities in China impose strict regulations on plant operators, who must provide proof that these have been met (inverter certification). Stringent requirements are also laid down in the USA. For example, inverters must be able to recognize when subgrids continue to operate independently despite higher grid levels being shut down and maintain the voltage. This can happen when generation and consumption are equally balanced in the subgrid (active islanding). Solar power plants must prevent this from happening.

How to start a project – Some important questions

Assessment of yield and capacity
Which technology is necessary to achieve the highest possible yield? What is the module area required? Is it possible that additional shading from new buildings or plant growth will occur at a later point in time?

Local support
Will the project be supported by representatives from local government and the local community? How can skeptics be won over?

Building permits, development plans and compliance testing
Has planning and building permission been granted? Does the land development plan permit the installation of a photovoltaic plant? Does the project conform to the national feed-in requirements?

Grid connection testing
Is a suitable grid connection terminal available on site? How long will it take to obtain grid-related information and to process the application?

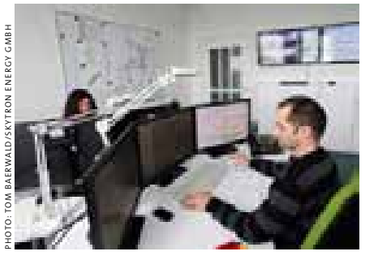


PHOTO: TOM BAERWALD/SKYTRON ENERGY GMBH

Monitoring systems increase the lifetime of solar plants and allow malfunctions to be detected promptly.

The turnkey implementation of large PV installations poses great logistical challenges to project planners.

PHOTO: TOM BAERWALD/PARABEL AG

PHOTO: TOM BAERWALD/SKYTRON ENERGY GMBH

Installation of monitoring hardware on site

Regularly checking plants on site is essential.

PHOTO: TOM BAERWALD

PHOTO: TOM BAERWALD/PARABEL AG

Possible contact and cable resistance means that the correct cabling of solar power plants is essential due to the threat of efficiency losses.

Early involvement of utilities

Rough technical planning is followed by submitting the feed-in application to the local utility. This has the purpose of determining the location of the entry point and whether it will actually be possible to feed the projected yield into the grid. Involving grid operators in planning at as early a stage as possible is therefore a must. If it is later discovered that additional investment is needed for grid feed-in, this can become very costly and jeopardize the entire project. If there are several possible entry points, the most cost-efficient point will be selected – no matter which part of the costs must be paid for by the plant investor, and which by the utility. The basic principle is: Grid connection costs must be borne by the investor, grid development costs by the utility. The utility also sets specific parameters for keeping the grid stable when power is fed in. The sooner grid operators are involved in the planning process, the quicker and more smoothly different connection scenarios, and the costs associated with them, can be investigated to find the optimum solution.

A word on logistics

Solar parks are complex building sites covering a large surface area. Transport logistics for modules alone requires careful planning. Crystalline modules, for example, are delivered in containers of 500 each (appr. 100 kW). A solar park with a capacity of 25 MW requires around 250 containers which can only be moved using designated lifting equipment (cranes, forklift trucks, etc.). Just-in-time delivery is vital to avoid costs for idle periods. The handling of modules – especially frameless modules – in particular calls for extreme care so as to avoid breakage or damage.

Monitoring

The operation of a solar park also necessitates great care. First of all, the smooth running of the plant must be ensured to avoid any interruptions. A sophisticated plant monitoring system will document operation, providing the basis for quarterly reports to investors and helping to identify the causes of any shortfalls. Faults at the entry point or the inverter are particularly critical, and engineers must respond quickly to minimize any yield losses. Since modern inverters provide remote monitoring options, faults do not always require a trip to the site.

Regular checks

PV plants in the MW range also require regular checks by staff. Regular visual checks, on-site thermal imaging, remote monitoring of strings and inverters as well as the evaluation and storage of data are indispensable. Operation and maintenance costs account for between three and five percent of the solar yield. If well planned and executed, they can increase the yield by a significant amount. To enable inspections to be carried out in a single day, it can make sense to employ helicopters or service drones.

Protection against theft

Ground-mounted systems need to be protected from theft and vandalism, the minimum requirements being a fence with climb-over protection and a secured access gate. Video monitoring and microwave or infrared sensor barriers with alarms via cable or radio complete the security concept. Of course, costs and benefits must be weighed up against each other in each individual case. Investment in such equipment will have paid for itself if it prevents just one occurrence of large-scale module theft. In the event of such theft, not only components are lost; consequential damage to the electrical system is common, as are significant yield losses. If such occurrences become frequent, there is a risk that insurance cover will be withdrawn, meaning that the investment will no longer be protected. At the very least, costs will be incurred to fit expensive anti-theft systems or employ additional security staff.

PHOTO: TOM BAERWALD/SKYTRON

Theft protection provided by video monitoring

“PV’s ability to provide grid support is underrated”

An interview with Dr. Winfried Hoffmann, President, European Photovoltaic Industry Association

PHOTO: EPIA

PHOTO: FIRST SOLAR

PV systems of all sizes can provide grid support services.

Large photovoltaic systems with more than one up to several tens of MW of power have gained growing market shares in the photovoltaics industry. What role do they play in restructuring the European energy sector?

It’s clear that the latest changes in national regulatory frameworks do not favour the development of large ground-mounted systems. In the short term, we should not expect dramatic development of this segment in the established markets. But with the continuous effort of the industry to decrease the cost of PV technology (and, as a consequence, its generation cost), large plants remain an important option for the decarbonisation of the EU electricity sector in the medium-to-long term. But this requires a redesign of electricity markets in order to ensure the profitability of such large-scale installations.

Large solar parks are able to stabilize the grid. How important is it for the rapid change in the system of electricity supply?

Well, these services are certainly necessary if we want to move from a fossil or nuclear-based, heavily centralized system to a clean, safe decentralized one. As PV increasingly becomes a player in the power system, it will have to provide more services to the grid. We are already working in close collaboration with DSOs and TSOs on the role of PV in the future power mix and also during the transition. With the support of our members EPIA is working on EU-financed projects like PV GRID or REserviceS that will help the transition. PV’s existing ability to provide significant grid support capabilities – including active power reduction, fault ride-through, and voltage support – is vastly underrated.

With increasing level of active power in the grid from solar parks or wind farms it might be more important to feed in reactive power. Which role can solar parks play in order to reduce the costs for new high-voltage or medium-voltage cables?

PV systems of all sizes can provide grid support services. The main advantages of large plants are the lower cost to provide the service and the ease of implementing communication. PV can participate in system operation either at the distribution or the transmission level. But it requires a cost-effective communication infrastrcuture, new system operation strategies that take advantage of PV’s capabilities, a better interaction between DSOs and a better understanding of what PV can provide. The effective use of PV capabilities can effectively reduce the need to extend the exisiting grid infrastructure.

Superstorm Sandy made it clear: The solar fields are the first generators returning to the grid after a blackout or shut-down of the grid in case of hazard or disaster. Do they diminish the risk of blackouts at all?

As EPIA showed in its “Connecting the Sun” report, large-scale PV integration in the European grid is technically feasible with a high level of security of supply, even under the most extreme weather and load conditions. With the right measures and investments in place, system reliability can be ensured. The concept of back start or restoration plans – restarting the system after a black out – is really complex. Currently PV is not integrated in such plans and is requested to disconnect during events. In a future with a lot of PV and with the development of the right measures, PV could serve as an emergency generation technology during critical events and help to restore the grids.

The most powerful voice of photovoltaics in Europe

EPIA – the European Photovoltaic Industry Association – represents members active along the whole solar PV value chain: from silicon, cells and module production to systems development and PV electricity generation as well as marketing and sales. EPIA’s mission is to give its global membership a distinct and effective voice in the European market, especially in the EU.

EPIA
European Photovoltaic Industry Association

EPIA – European Photovoltaic Industry Association
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info@epia.org
www.epia.org

Companies

PHOTO: TOM BAERWALD/PARABEL AG

Companies and brands presented at a glance (in order of appearance)

Companies (in alphabetical order)

Page	Company	System integrator/project developer/turnkey solutions	Inverter/inverter systems	Crytalline module manufacturing	Thin-film manufacturing	Storage systems	Tracking systems	Mounting systems	PV monitoring systems	Component suppliers	Operation and maintainance	Grid integration	Power plant control	IT solutions	Logistics	Certifier	Consultant
44	3E	●							●		●						●
45	ABB		●														
46	Activ Solar	●									●						
47	Advanced Energy		●						●	●	●		●				●
48	AEG Power Solutions GmbH	●	●			●			●	●	●		●				
49	Alternative Antriebe & Erneuerbare Energien																●
50	AXITEC GmbH			●													
52	BELECTRIC Solarkraftwerke GmbH	●						●	●		●	●	●	●	●		
51	Bonfiglioli Riduttori S.p.A.		●														
54	Dow Corning Corporation			●	●			●		●							
55	F&S solar concept GmbH	●		●					●		●	●	●				
56	Fronius Deutschland GmbH		●						●								
57	GP JOULE GmbH	●															
58	Ingeteam Power Technology, S.A.		●						●		●						
60	Mounting Systems Group							●		●							
59	Nuevosol Energy							●									
62	Platinum® GmbH		●						●								
63	Power-One		●			●			●				●				
64	PROFIL DU FUTUR							●		●							
65	Schneider Electric	●	●				●			●	●	●					
66	skytron® energy GmbH	●							●	●	●	●	●	●			
67	SMA Solar Technology AG		●						●			●	●				
68	SolarMax		●						●								
69	SolarWorld AG	●		●		●		●	●		●	●	●				
70	Solectria Renewables		●						●								
71	TÜV SÜD											●	●			●	

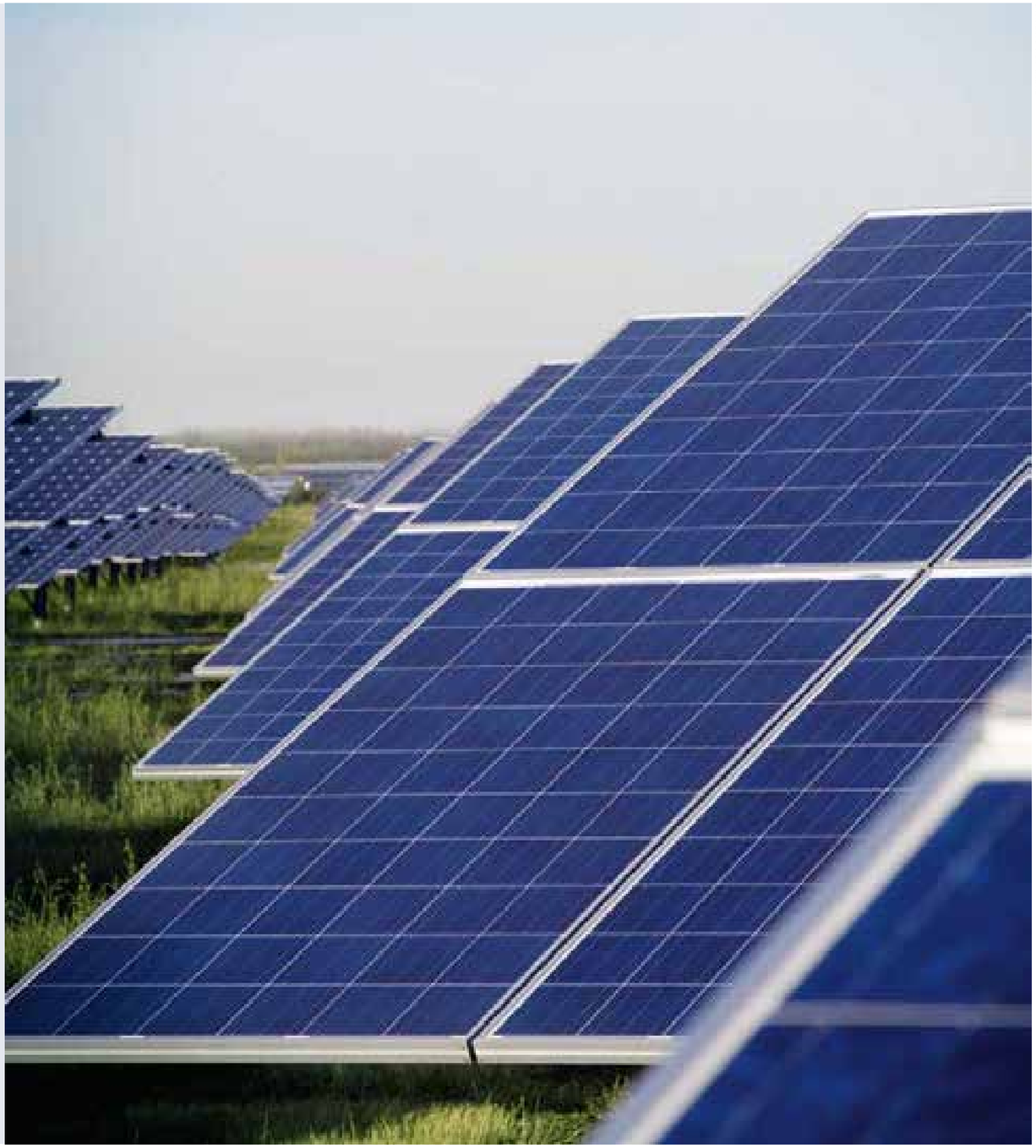
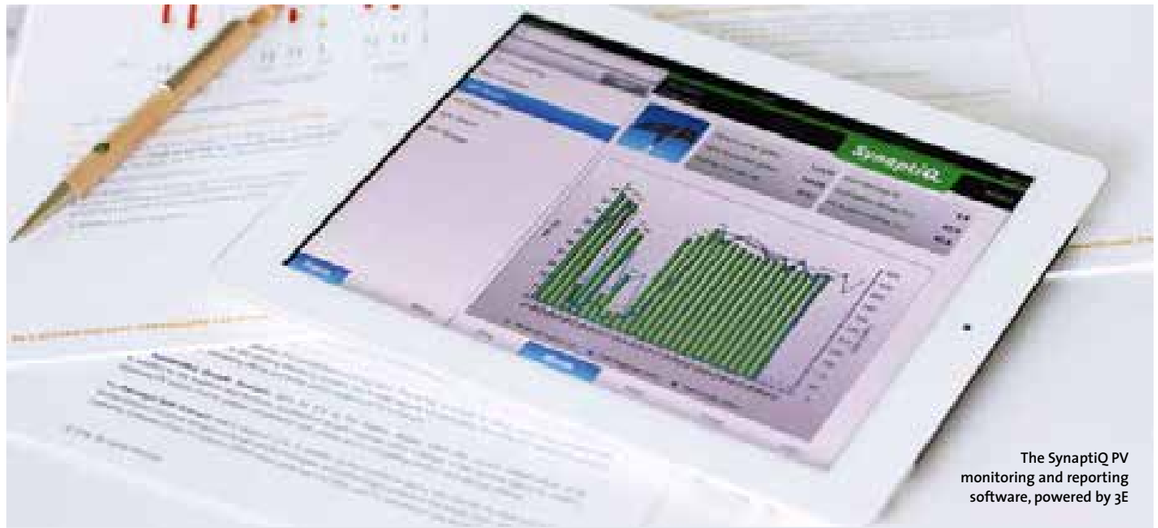


PHOTO: TOM BAERWALD

Technical Consultancy and Software Services for Sustainable Energy



The SynaptiQ PV monitoring and reporting software, powered by 3E

3E is an independent technical advisor specialized in renewable energy and energy performance optimization. We provide expert consultancy services and software products throughout the full project life-cycle.

Since 1999, 3E has focused on serving investors, project developers and product developers with technical expertise to reduce risk and optimize performance throughout the full life-cycle of PV parks. Operating from Brussels (HQ), Toulouse, Milan, Istanbul, Beijing and Cape Town, the company has a project track record of more than 15 years in over 30 countries, and is a trusted partner for the major lenders and equity providers in the global renewable energy market.

In photovoltaics, 3E provides expert consultancy services, including resource modeling, development guidance, system engineering, technology assessments, due diligence and risk mitigation strategy, in addition to system monitoring and reporting tools. We have worked on ground-mounted and rooftop systems from 10 kWp to multi-megawatt projects, including utility-scale projects of up to 75 MWp. We have helped our clients to reduce risk and optimize the performance of their projects in Belgium, France, Italy, Greece, Croatia, South Africa and several other countries. We have also carried out factory audits and assessments on over 45 PV module manufacturers in China, Europe, India and Japan.

SynaptiQ, 3E's monitoring and multi-stakeholder reporting software platform, is designed for performance optimization of multi-brand and multi-technology solar portfolios. SynaptiQ is a flexible and intelligent software tool, compatible with a very wide range of hardware devices (inverters, loggers, SCADA, etc.). The platform is already connected to over 1,000,000 components in utility-scale PV parks in ten countries.

Our consultancy and software services are enhanced and strengthened by an in-house research and innovation lab, specialized in modeling and data analysis. Bridging the gap between R&D and the market, 3E combines this in-house innovation, partnerships with leading R&D centers and a thorough understanding of practical industry needs to continuously offer high-performance, cost-effective services and products.

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claire.grandadam@3E.eu
www.3E.eu
Founded: 1999
110 employees

Bankable ABB Central Inverters for Large-Scale PV Power Plants

ABB's compact turnkey megawatt station (top right)

ABB's successful central inverter series, the PVS800, confidently meets your bankability requirements (top left).

Global production capabilities are a key ingredient for bankability (bottom right).

Bankability is of extreme importance when choosing a solar inverter supplier, especially for large-scale PV plants. ABB central inverters meet all bankability requirements, making them a choice that you can confidently trust.

During the last ten years, ABB has delivered over 100 GW of power converters on the same platform that is used for ABB central inverters, which, after only a few years on the market, have now nearly reached 1 GW of installed capacity.

ABB's successful central inverter series, rated from 100 to 1,000 kW, is designed for multi-megawatt photovoltaic (PV) power plants. The inverters give a high overall efficiency coupled with a compact and easy-to-maintain design. The 1,000 kW central inverter has a maximum efficiency of 98.8% and a European Efficiency rating of 98.6%. This, together with a very low auxiliary power consumption of only 630 W, results in the outstanding overall efficiency of our inverters. In addition, the wide temperature range and altitude rating, as well as a modular DC input layout, provide much greater flexibility for system integrators.

Power density is almost 20% higher than earlier central inverters, allowing savings to be made in installation space and transportation costs. Also, thanks to the inverters' certificates and advanced, flexible grid-support functions, ABB central inverters meet all applicable network connection requirements.

ABB also supplies a megawatt station which is a turnkey solution for large-scale solar power generation. The megawatt station houses all electrical equipment needed to rapidly connect a PV power plant to a medium voltage (MV) electricity grid. All components are from ABB's proven technology portfolio, providing high efficiency and reliability in a compact, easy-to-maintain unit.

In the end, your choice of inverter comes down to what makes you most confident about meeting your return on investment (ROI) goals. ABB central inverters do just that, with bankable credentials that you can trust.

ABB Oy, Power Conversion
Hiomotie 13
00380 Helsinki
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Phone: +358 (0)10 22 11
feedbackmaster.solar@fi.abb.com
www.abb.com/solar
Founded: formed in 1988, merger of Swiss and Swedish engineering companies with predecessors founded in 1883 and 1891
145,000 employees (ABB Group)

Activ Solar

A Global Company Focused on the Development and Manufacture of Solar-Based Technology

82.65 MWp Ohotnikovo solar power station (Crimea, Ukraine), one of the largest solar parks in Eastern Europe (left)

105.56 MWp Perovo solar power station (Crimea, Ukraine), one of the largest solar parks in the world (above)

Vienna-based Activ Solar is a solar industry pioneer focusing on emerging solar markets, where it has built some of the world's largest photovoltaic installations.

Activ Solar's main business areas include the development, financing and completion of large-scale photovoltaic installations in emerging solar markets, as well as the production of polysilicon at a wholly-owned semiconductor plant in Ukraine.

Project development

- significant track record of solar developments and technical know-how to select and carry out projects with the highest expected returns
- own equity to co-invest, enabling project risks to be shared
- pipeline of processes typically performed with local partners to make projects shovel ready

Financial solutions

- background in finance & investments with strong track record in energy M&A and project finance
- strong track record in securing project finance from commercial banks and ECAs, and in obtaining vendor finance
- broad network of international and local investors to facilitate exits, if needed

Asset management

- team with extensive experience in maximizing value and returns of operational portfolios
- management and maintenance of parks
- current assets under management of 400+ MW

EPC

- engineering team with proven track record of designing optimal large-scale utility PV parks
- excellent relationships with major bankable suppliers and "buying power" thanks to large procurement volumes (approximately 400+ MW over two years)
- construction management capacity worldwide

Facts & figures

- established in Vienna, Austria, in 2008
- over 1,700 professionals worldwide
- over 400 MW of utility-scale projects developed, financed and put into operation to date
- long-standing relationships with multiple tier one suppliers
- ranked globally as a top five developer of large-scale solar PV projects
- developed, financed and constructed some of the world's largest solar PV power stations

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www.activsolar.com
Founded: 2008
1,700 employees

Advanced Energy

ENERGY DELIVERED™

AE's power stations generate electricity dependably, optimize Levelized Cost of Energy (LCOE) and help stabilize grid operation.

150 MW solar project utilizing AE's 2 MW integrated skid solutions

Solar plant in Vermont State, USA

AE's solar energy business delivers highly reliable inverters, complementary Balance of System (BoS) products, and robust Operations and Maintenance (O&M) services that allow its customers to secure more solar projects and increase their earnings.

Customer experience

AE Solar Energy enables utility-scale and commercial solar project stakeholders to offer system owners a lower Levelized Cost of Energy (LCOE) and confidence their PV system will deliver on long-term production goals. With more than 30 years of leadership delivering innovative energy solutions, combined with a legendary reputation for customer service and a strong balance sheet, AE Solar Energy is a trusted partner for solar project developers, EPC companies, financiers and beneficiaries around the globe.

Innovation

AE is never satisfied: From our roots in reliability and LCOE to continually improving our quality, systems and people, we ensure that energy is delivered, period. We pioneer improvements in distributed generation, grid interactivity performance, utility interactive functionality, and energy management solutions.

ENERGY DELIVERED™

AE delivers highly reliable and efficient inverters designed with an architecture optimized to deliver the lowest possible LCOE. Our simplified BoS solutions reduce system design support, project management time and increase savings on installation. Simply put, AE delivers life-cycle performance.

Solar site services

AE delivers whole-site operations and maintenance service plans that increase the reliability of customers' PV systems. AE global services are dedicated to responding quickly to issues, whether that means rolling a truck, providing phone support or anything in between. We provide application engineering support and warranties for up to 20 years, partnering with customers for the entire project life-cycle.

AE Solar Energy
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Fax: +1 541 312-3840
sales.support@aei.com
www.advanced-energy.com/solarenergy
Founded: 1981
1,500 employees

HIGH-VALUE SOLAR POWER GENERATING PRODUCTS AND SERVICES

Eastern Europe, > 300 MW
AEG PS provided complete electrical systems for several PV power plants.

AEG Power Solutions –
Competence Center Warstein-Belecke

Central Inverter Protect PV.800

Building on its proven track record in supplying utilities and grid operators with reliable, fully-compliant solutions, the Protect PV.250, PV.500, PV.630, and PV.800 solar inverters from AEG PS provide quality and efficiency for large-scale PV installations. With an efficiency of more than 98% and compliance with European and American standards, AEG PS solar inverters exceed the expectations of their power class. The innovative FPGA circuits ensure the flexible, precise and rapid control needed to meet virtually all national grid standards.

In addition to solar inverters, AEG Power Solutions offers two completely integrated stations. The first is the TKS-C container solution, which includes Protect PV solar inverters along with a medium-voltage transformer, switch-gear, and a monitoring, measurement and control system. The second is the Compact Station, which places the solar inverters in metal housings that are separate from the transformer, switch-gear, and MM&C system. These single-source solutions ensure smooth PV power plant operation, in close cooperation with grid operators.

Both integrated systems include intelligent combiner boxes installed in the PV array's field. These combiner boxes are fully integrated via communication links to field sensors for temperature, radiation and weather, and the collected data is stored in data loggers. The monitoring software, from our subsidiary skytron energy, called PVGuard, ensures that the status updates needed by PV plant operators are always available over the Internet.

Backed by decades of field experience, AEG Power Solutions has built its worldwide service reputation by constantly exceeding customer expectations throughout the product lifespan. AEG Power Solutions' service starts right from the beginning of any project installation. Clients can rely on AEG PS for service and support over the entire life-cycle of the plant. With facilities across Europe, the Middle East, Asia, China and North and South America, AEG Power Solutions is on hand for collaboration with all potential partners, including EPCs, consultants, operators and investors.

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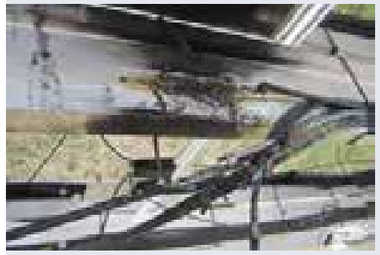
Phone: +49 (0)2902 763-141
Fax: +49 (0)2902 763-1201
solar@aegps.com
www.aegps.com
Founded: 1946
Turnover: 368 million euros (2012, worldwide)
> 1,600 employees (2012, worldwide)

Quality Control Safeguards Sustainable Yields



Reduction in yield resulting from shading caused by plant growth (top left and right)

Reduction in yield resulting from shading caused by the system itself (left middle)

Burnt off plug connector and damaged DC cables (left bottom)

The engineering office Alternative Antriebe & Erneuerbare Energien has a wide range of clients, including system buyers (investors) and sellers (system constructors and operators), as well as money-lending institutions (banks).
The company's founder, graduate engineer (Diplom-Ingenieur) Christian Dürschner, looks back on many years of experience as a project engineer and independent expert in photovoltaic systems. He founded the consultancy firm Alternative Antriebe, which focuses on solar cars, electric cars and hybrid vehicles, as early as in 1995, before expanding it into Alternative Antriebe & Erneuerbare Energien, an engineering office specializing in photovoltaics, in 2000. Certified as having expertise in photovoltaic systems by the German Technical Inspection Association (TÜV), the office mainly draws up objective and impartial reports for small, medium and large-scale PV plants.

Our range of services from A to Z:

- analysis of yield reductions
- comparison of actual and nominal yields
- creation and evaluation of yield forecasts and yield reports
- damage reports and damage evaluations
- expert opinions for court cases
- I-V curve measurements of modules and strings
- inspections using electroluminescence and/or thermal imaging cameras
- profitabiltiy calculations
- quality assurance of construction processes
- support with EEG commissioning
- support with technical acceptance
- technical due diligence
- valuation of existing plants
- and much more...

Benefit from our long-standing experience in PV!

Alternative Antriebe & Erneuerbare Energien
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www.pv-gutachter.de
www.solar-buch.de

www.axitecsolar.com
AXITEC
high quality german solar company

A Leading Module Manufacturer with Headquarters in Germany and Worldwide Production Locations

Spain: utility power plant (right)
Spain: Expo Zaragoza 2008 (top left)
Germany: system installed on logistics center roof in Hamburg (bottom left)

12 years manufacturer's warranty

MADE IN ASIA
MADE IN EUROPE

Brands of AXITEC: "Made in Asia", "Made in Europe"

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71034 Böblingen
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Phone: +49 (0)7031 6288-5186
info@axitecsolar.com
www.axitecsolar.com
Founded: 2001
20 employees

With 300 MWp of solar modules installed across the globe, German company AXITEC GmbH has been established for years as a high-performance and quality module manufacturer.

AXITEC GmbH was established in 2001 and has been one of the leading global manufacturers of quality solar modules for years. The core expertise covers the complete process chain for solar modules from development and manufacturing through quality assurance to sales and service.
High-performance solar modules by AXITEC are sold all over the world under two different brands. They are manufactured in accordance with their respective labels – "Made in Europe" and "Made in Asia" – in the respective production facilities of certified OEM partners. AXITEC grants identical warranties for all of them:
- positive tolerances
- twelve-year manufacturer's warranty
- exclusive linear AXITEC performance guarantee

Global production processes
Years of close partnerships with several OEM manufacturers enable AXITEC to always use the latest technology in the manufacture of solar modules, making it one of the leading global providers in terms of technology and cost. AXITEC customers can therefore purchase solar panels with an excellent price-performance ratio.

Quality assurance and certification
AXITEC solar modules are certified according to all international standards, e.g. IEC, UL, MCS and CEC. Additionally, all solar modules are certified according to IEC 61701 (Salt Mist Corrosion Test) and IEC 62716 (Ammonia Corrosion Test). As a result, all AXITEC solar modules can be mounted next to the sea and on agricultural roofs, including those of pigsties.

Global branch offices
AXITEC has branch offices in Italy, the USA and Brazil. Additionally, AXITEC solar modules are available worldwide from renowned distributors, whose objective is to appeal to customers and demonstrate the products' technology.

References and installations
All over the globe, AXITEC solar modules successfully produce clean energy.

Bonfiglioli
power, control and green solutions

Bonfiglioli – Partner in Large Projects. Worldwide.

Parvomay, Bulgaria: SunEdison
60 MW PV field entirely equipped with Bonfiglioli RPS TL inverters

Bonfiglioli RPS Station

Puertollano, Spain (51 MW): the world's largest PV field in 2008, equipped with Bonfiglioli inverters

Bonfiglioli Riduttori S.p.A.
Via Giovanni XXIII, 7/A
40012 Lippo di Calderara di Reno – Bologna
Italy
Phone: +39 0516 473-111
Fax: +39 0516 473-126
photovoltaic@bonfiglioli.com
www.bonfiglioli.com
Founded: 1956
3,300 employees

Bonfiglioli manufactures and designs power conversion systems from 3 MW turnkey solutions down to 30 kW compact devices, for medium-to-large commercial and utility-scale installations.

Thanks to the global nature of its distribution network and a wide range of high efficiency solutions, prestigious international engineering, procurement and construction contractors (EPCC) and independent power producers (IPP) trust Bonfiglioli to supply the inverters needed for large-scale photovoltaic installations in Europe, Asia and North America. In 2008, Bonfiglioli supplied its solutions to the world's largest photovoltaic field at the time (51 MW), which is located in Spain. In 2010, Bonfiglioli supplied the inverters for one of Europe's largest PV fields (70 MW) in Italy and in 2012, a 60 MW PV field equipped with Bonfiglioli inverters came on line in Bulgaria. Its long history and consolidated international presence make the company a reliable and bankable investor, and have allowed the Bonfiglioli Group to contribute to the start-up of major installations in emerging markets.

Bonfiglioli's RPS Stations, which are available in a vast range of power ratings from 280 to 3,100 kW, provide turnkey solutions for the complete photovoltaic field management of all large-scale ground installations. RPS Stations are produced and tested directly at the plant to ensure the highest standards of quality and efficiency alongside reduced costs. As a result, customers can take delivery of a fully equipped, ready-to-connect system in impressively short times.

The RPS TL modular inverters at the heart of every Bonfiglioli RPS Station guarantee the highest system yields and excellent international grid code compatibility, thanks to the modular engineering and German technology that distinguish all Bonfiglioli inverters.

An in-depth understanding of markets and market dynamics, 17 commercial subsidiaries, four photovoltaic production centers on three continents and a wide range of high-tech inverters make Bonfiglioli a long-standing and riskless industry player for photovoltaic field developments anywhere in the world.

BELECTRIC®

Solar Power Plant Templin with
First Solar modules, 128.4 MWp (left)

The world's first solar power plant
operating at 1,500 V DC voltage (top right)

BELECTRIC's in-house R&D division (middle right)

BELECTRIC employs over 500 construction
workers worldwide (bottom right).

Photovoltaics 3.0: Made for Efficiency

Solar Power Plant Puyloubier, 6,495 MWp;
constructed for EDF Energies Nouvelles

Powerful, efficient and grid friendly: With the 3.0 MegaWattBlock, BELECTRIC is setting new standards in solar power production.

On a par with the functionality of large conventional power plants, BELECTRIC's grid stabilizing power plant technology makes it possible to intelligently integrate renewable energy sources into existing power grids. This means that grid expansion caused by renewable energy can be kept to a bare minimum.

We design energy

BELECTRIC is one of the world´s leading companies in the development and construction of ground-mounted solar power plants and roof-mounted photovoltaic systems. As an international corporation, BELECTRIC has permanent offices in more than 20 countries, meaning it is able to reach almost every part of the globe. In 2012, BELECTRIC achieved a historic milestone by becoming the first systems integrator in the world to install 1 GW of solar power.

BELECTRIC designs, manufactures and constructs photovoltaic systems. The company offers a wide spectrum of solar energy solutions, ranging from utility-scale solar power plants to photovoltaic rooftop installations and solar-optimized e-mobility charging boxes. Engineers and technicians conduct interdisciplinary research in all areas of photovoltaics and develop innovative technology that forms the basis for the environmentally friendly power supply of our future. In 2012, the company looked back at a success story involving 100 patented innovations in the field of photovoltaics, and since being founded has implemented over 2,700 photovoltaic rooftop installations and more than 200 solar power plants worldwide.

BELECTRIC realizes photovoltaic solutions with a degree of almost 100% vertical integration along the value chain. This relates especially to the area of complex solar power plants and ranges from systems engineering and the manufacture of balance of system (BoS) components, through to O&M service packages. BELECTRIC consistently promotes photovoltaic modules with modern thin-film technology and has established long-term joint ventures with leading manufacturers in this field. By covering and optimizing virtually all areas of the solar business, BELECTRIC achieves the lowest levelized cost of energy (LCOE) in the photovoltaics business.

3.0 MegaWattBlock: reliable technology full of innovation

With a design that focuses on standardization, optimization and grid integration, we build solutions that perfectly match our customers' demands and the world's energy needs. All of these are combined in the 3.0 MegaWattBlock.

BELECTRIC has a successful history of product evolution with its 2.0/2.5 MegaWattBlock and is taking the same approach with the new 3.0 MegaWattBlock. The high power generating unit has been developed to construct top performance utility-scale solar power plants. The standardized modular design was formed with a simple goal in mind: to create a solar power plant that delivers power at the lowest possible cost. Designed with the aims of saving resources, fast construction and reliable operation, the new unit is synonymous with an optimum cost-benefit ratio.

Proving its technological leadership once again, BELECTRIC operates the 3.0 MegaWattBlock at a voltage of 1,500 V. The new system uses the full power bandwidth defined by the EU's Low Voltage Directive, enabling efficient grid integration and significant cost reduction at the same time.

New technology: for a stable power grid

The new generation of photovoltaic systems produces solar power that is commercially viable in relation to fossil energy sources and provides additional grid services. Today, BELECTRIC already uses innovative power plant technology that can stabilize our power network night and day. This generates new capacities for renewable energy sources and prevents the additional construction of new transmission line routes.

With the 3.0 MegaWattBlock, BELECTRIC provides an essential component for sustainably stabilizing power grids. The solution comprises an intelligent control unit that can be used to smoothly integrate the new product range into worldwide power grids and combine them with conventional power plants. This new technology contributes significantly to improving grid stability for operators and consumers, as well as establishing photovoltaics as a decisive part of the energy mix and making the costly extension of the power grid redundant.

BELECTRIC – The Better Electric

Solar Power Plant Bochow with
Solar Frontier modules, 28.8 MWp

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Fax: +49 (0)9385 9804-590
info@belectric.com
www.belectric.com
Founded: 2001

Dow Corning Corporation

Solar Solutions

DOW CORNING

Reliable Silicon Solutions for Solar PV

Unleash the solar power of silicon

As the PV industry assumes an increasingly important role in meeting the world's energy needs, Dow Corning Corporation is committed to helping the industry grow and succeed.
Dow Corning Corporation provides silicon-based solutions across the PV value chain, including feedstocks and a wide range of other material options, improving the performance and durability of finished solar modules.

A growing portfolio of solutions

As a leading materials supplier to the PV industry, our goal is to help our customers grow through innovation and material solutions across the entire solar value chain. Our portfolio of solutions includes:

- silicon feedstock
- conductive adhesives, coatings and cell applications
- silicone encapsulants
- junction box adhesives and potting agents
- silicone sealants and adhesives for module finishing
- structural sealants for module installation

Investing in the success of the PV industry

Our long-term commitment to sustainability and to providing solutions to the PV industry is demonstrated by major investments in Solar Solutions Application Centers around the world.
Dow Corning's state-of-the-art PV module and solar cell application centers enable close collaboration with industry leaders and testing and application development to be carried out on site.
Driven by innovation and fueled by 70 years of talent, expertise and capabilities, Dow Corning delivers silicones, silicon-based technology and high-performance products that help create more reliable solar systems to increase the number of kilowatt hours of output and profitability.

You can learn more about Dow Corning Solar Solutions and view our virtual trade show at dowcorning.com/solar or e-mail solar.solutions@dowcorning.com.

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solar.solutions@dowcorning.com
www.dowcorning.com/solar

Founded: 1943
Turnover: 6.43 billion USD
12,000 employees (worldwide)

F&S solar concept GmbH

F&S SOLAR

Complete Solar Solutions – Made in Germany

Schwege solar park (top left):
36,000 modules – 8,254 kWp output

Lüneburg solar park (bottom left):
11,264 modules – 2,703.36 kWp output

Saerbeck bioenergy park (top right):
23,920 modules – 5,740.80 kWp output

Inden solar park (bottom right):
16,236 modules – 3,815 kWp output

Having already installed more than 1,500 solar power plants, F&S is one of the most important plant engineers across Europe.
Institutional investors, family-run offices as well as utility and public utility companies rank among our clients.

F&S solar specializes in the planning, development and subsequent construction of solar parks worldwide.
Top priority is given to ensuring that all of the company's power plants fulfill high quality requirements, with everything right down to the smallest detail being regulated by RAL certification.
Extensive final acceptance inspections ensure that each system is in full working order, meets technical regulations and operates fault-free.
In addition to exceptional technical expertise, the company also offers legally compliant plant operation models.
In a further department, F&S solar's engineers and technicians develop bespoke, finely-tuned solutions for roof-mounted installations. The roof covering is examined and the amount of shading evaluated during an on-site meeting.

Following this, customized plans for the entire system are drawn up in close collaboration with the plant operator.
The range of services is rounded off by comprehensive plant monitoring, a 24-hour emergency service and a sustainable maintenance system. On request, F&S solar can also act as technical plant managers for institutional investors.
At F&S solar, quality "Made in Germany" remains a guarantee for a secure investment.

F&S solar concept GmbH
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www.fs-sun.com

Founded: 2007
Turnover: 75 million euros (2011)
50 employees + 250 service technicians

SHIFTING THE LIMITS

Fronius: Reliable Solar Solutions

Inverter room at the PV power plant in Eberstalzell (Austria), 1.1 MW, 9 Fronius Agilo 100.0

Decentralized inverter concept for east-west orientation, 2.1 MW, 148 Fronius IG Plus 150

Fronius production plant & logistic center in Sattledt (Austria)

State-of-the-art technology in high-performance electronics, the use of high-capacity processors and the interconnection of stand-alone devices are the keys to success for Fronius.

Fronius, with its headquarters based in Austria, has been conducting research into new technologies for converting electrical energy since 1945. That means more than 60 years of experience, progress and constant innovation. Its outstanding products and services have made Fronius a technology leader on the world market.

The German subsidiary – Fronius Deutschland GmbH – was founded in 1993. Its headquarters are based in Neuhof, located in the heart of Germany. There, all three Fronius divisions, Solar Electronics, Battery Charging Systems and Welding Technology, are consolidated under one roof.

Quality and high-tech

Fronius' solar electronics division has been in existence since 1992 and its products are sold through a global network of sales partners. The division develops and produces high-powered inverters for mains-connected solar power plants of any size. The product range is rounded off with an extensive selection of components for professional plant monitoring, data visualization and analysis.

In the development of PV inverters, Fronius has thought out new technologies, searched for innovative solutions and found completely new answers. The result: highly functional mains-connected inverters, which interact optimally with all solar modules.

From open-field PV power plants with a challenging topographic structure to complex rooftop systems – Fronius provides individual systems which reduce the cost of ownership. Low maintenance, minimized downtime and a longer lifespan of the implemented solar electronics are the result. This guarantees stability of yield and an attractive return on investment from the project.

Fronius inverters are perfectly suited to solar systems in the upper megawatt range, as they ensure economical operation with maximum yield.

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www.fronius.de
Founded: 1993
210 employees

GP JOULE
Simply energy!

The Field-Grown Specialists – Success Is in Our Nature

Energy quartet in Pompogne: four areas with a total of 40 MW

Series-ready hydrogen storage system from H-TEC

Solar park in Bosbüll with a total of 15.6 MW

GP JOULE specializes in megawatt-class power plants. Solar is the main focus area, although the company also successfully implements wind and biomass projects.

Ove Petersen, CEO, defines the vision behind GP JOULE: "Our strength doesn't only lie in plant construction. We also specialize in solutions for the future. We are certain that 100% renewable energy is a realistic goal and can show you how to achieve it in just a few years."

The company is headquartered in North Germany. In addition to sites in the south of the country, GP JOULE is also represented in France, Italy, the USA and Canada, and is active in projects all over the world.

Good prospects: ecology meets economy

The major advantage of the expert energy company lies in the way it accompanies projects along the entire value chain. From development, planning and finance, to plant construction, GP JOULE offers all necessary services and can even provide turnkey plants on request. The business's investment division is dedicated to the successful combination of ecology and economy.

The company also offers a high-quality range of technical and commercial services for solar and wind parks that guarantee long-term stable yields.

Better today than tomorrow: energy solutions

GP JOULE is constantly striving for progress, and not just in its future concepts division. Its series-ready storage solution using hydrogen technology was presented in 2012 in cooperation with the subsidiary H-TEC: the PEM-electrolyser provides a key to the future of renewable energy.

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Founded: 2009
100 employees

Ingeteam Power Technology, S.A.

"The formula of the new energy: i + c"

Right: 70 MW PV power plant in Rovigo (Italy) powered with 60 Ingecon® Sun Power Max inverters

Above: Off-grid PV installation in Indonesia powered with Ingecon® Hybrid inverters

Below: Ingecon® Sun Power Max Outdoor up to 1 MW inverter

At Ingeteam each project is addressed from the concept of i+c – innovation to develop the optimal solution and commitment to provide an excellent service.

With manufacturing facilities in Spain, China and the USA, and subsidiaries in Germany, Italy, France, the USA, the Czech Republic, Poland, Brazil, Mexico, South Africa, China, Chile and India, Ingeteam can satisfy the needs of its clients worldwide. Furthermore, Ingeteam's Service Division provides operation and maintenance services to solar PV installations worldwide.

In the field of solar energy, Ingeteam has already overcome technology, and regulatory and integration roadblocks to offer holistic electrical equipment solutions in many solar installations operating throughout the world.

Ingeteam's latest innovations include the new Ingecon® Sun Power Max 1 MW central inverter for large-scale PV installations, which reaches an output power of 1,019 kW and a maximum efficiency of 98.8%. In order to meet households' new energy needs, Ingeteam has also just presented the Ingeteam Smart House concept, a global energy management solution for residential and industrial use that allows for increased on-site consumption. Moreover, Ingeteam has launched the new Ingecon® Sun 1Play (2.5 to 10 kW) and Ingecon® Sun 3Play (10 to 40 kW) inverter families with improved features that include higher efficiency levels. Finally, the Ingecon® Sun Training platform offers a wide range of on-site training courses and live webinars aimed at professionals in the PV sector.

Ingeteam is a global corporation specialized in six different sectors (energy, industry, marine, traction, basic technologies and services) that are all customer oriented and based on power and control electronics, electrical machines and application engineering. Thanks to its division-based structure and sustainable growth policy, Ingeteam enjoys a privileged, competitive position and has strongly established itself as one of the leading companies in the electronics and electrotechnical sector.

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Fax: +34 944 039-800
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Founded: 1972 (Ingeteam Group)
3,000 employees (Ingeteam Group, worldwide)

Nuevosol Energy

Mount Your Investments on Intelligent Structures

Left: Single-poled fixed mount structure, 20 MW

Top right: Two-poled fixed mount structure, 6.35 MW

Bottom right: Single-poled fixed mount structure, 25 MW

Nuevosol Energy is a leading provider of optimized mounting solutions with over 150 MW of installations to date. Through optimal solutions, it has fostered grid parity in emerging solar industries like India.

Definite solutions addressing infinite possibilities

Nuevosol's portfolio includes mounting solutions encompassing all segments. Our philosophy of mounting structures rests in the triumvirate of customization, standardization and innovation.

Optimized mounting at competitive pricing

Nuevosol's mounting solutions are a result of multifaceted optimization to create globally competitive solutions.

Intelligent structures with impeccable quality

A highly integrated design process with contributions from the R&D, manufacturing and installation teams results in intelligent structures, which can withstand wind loads of more than 180 km/h and resist harsh environments for 25 years.

Ground-mounted solutions

Nuevo ULTIMA: For mega power plants available with adjustable tilt and contour adapting models.

Lowering costs – fostering grid parity

We believe in finding an optimal solution to achieve grid parity, with leaner designs and lower costs for commissioning.

Global compliance

Our design team is experienced in producing globally compliant structures following country specific codes and standards.

Why choose Nuevosol?

- 150 MW of installations in diverse settings such as deserts, coastal areas, extremely humid regions, areas prone to corrosion and undulating ground
- global clientele including juwi Renewable Energy, Azure Power, Solairedirect, Waaree Energies, Refex Energy, EMMVEE Solar and Premier Solar
- ten-year warranty
- designs simulated and tested using sophisticated tools and prototyping
- designed for ease of assembly on site to achieve a pace of 2 MW per day

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50 employees

the base for solar power
Mounting structures as the base of every PV power plant

Sigma II open terrain system, reference: Eberswalde, Germany, 84.5 MWp, 2010–2011

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Founded: 1993
250 employees

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info@mounting-systems.us
www.mounting-systems.us

With 20 years of market expertise, ISO-certified Mounting Systems GmbH is one of the world's leading developers and manufacturers of photovoltaic substructures.

Top: Mounting Systems GmbH, Rangsdorf, near Berlin, Germany
Bottom: Mounting Systems, Inc., West Sacramento, California, USA

In 2010, Mounting Systems opened a representative office in Lyon, France. Since 2011, the company has established its own sales and production site in West Sacramento, USA. An additional representative office has been available to customers in Milton Keynes, Great Britain, since March 2012. Further international subsidiaries are planned.

The comprehensive product portfolio includes several fastening systems and components for photovoltaic and solar thermal installations. The international company provides innovative and customized solutions for large commercial open terrain projects and solutions for residential and commercial on-roof, in-roof and flat-roof systems, alongside leading-edge technology, professional project support and flexible production capabilities in aluminum processing. Mounting Systems' products are delivered from the company's sites in Rangsdorf and West Sacramento to over 50 different countries.

Mounting Systems – the expert for PV power plants

"Our day-to-day ambition is to develop, produce and supply innovative products, system solutions and services to all customers, especially in the PV power plant market," says Helge Tost, Director of Sales & Marketing. "We provide customized product solutions – quickly, with proven structural analysis and an accurate price/performance ratio. Our highly experienced project team creates fastening systems for large PV power plants for any terrain using concrete foundations, earth screws or the ramming post system to meet our customers' needs. Mounting Systems makes PV power plants happen, because we are the base for solar power."

Omega – when size matters

Omega was specially designed for use in large photovoltaic systems in harsh ground and soil conditions with strong wind and heavy snow loads. The modules can be arranged in any number of rows and columns on the module table in an area of up to 45 m² (portrait and landscape orientation).

- True innovation: short installation times guaranteed
- Environmental win-win: Minimum module elevation of one meter above ground surface prevents waste and allows secondary use of the terrain as pasture land

Sigma I – the specialist on uneven terrain

Sigma I was designed as a ground mounting system for installations where cost is of primary concern. Whether portrait or landscape, the system is also well-suited for framed and unframed modules. The use of driven piles eliminates the need to level the ground and makes the Sigma I system aesthetically pleasing and economical – ideal for large projects.

- Intelligent design allows installation on uneven terrain parallel to the ground surface
- Time and cost savings from use of driven piles and high level of pre-assembly

Sigma II – the space-saving open terrain professional

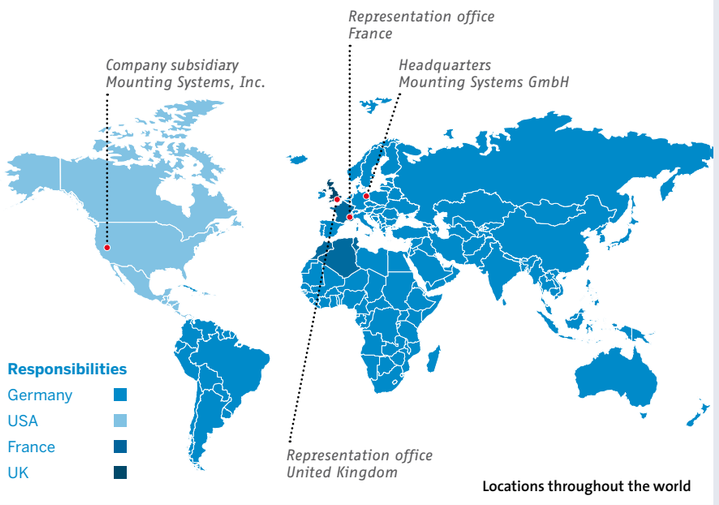
Sigma II allows the arrangement of several rows of modules either in portrait or landscape orientation. Depending on the project requirements, the Sigma II system is connected to the ground with driven piles, screw foundations or foot plates on concrete foundations. The system is characterized by a simple, functional design and reduced use of tools during assembly on site. For large projects, this means high cost savings with respect to assembly time.

- Maximum installation cost reduction through optimized installation time
- Easy dismantling allows for re-use or regeneration of terrain

Sigma I, the specialist on uneven terrain

Sigma II, the space-saving open terrain professional

Omega, when size matters



Locations throughout the world

From top to bottom:

- Sigma I open terrain system, reference: Laudenbach, Germany, 11.15 MWp, 2010
- Sigma II open terrain system, reference: Boulder Valley Church, USA, 200 kWp, 2011
- Omega open terrain system, reference: El Calaveron, Spain, 2 MWp, 2008

PLATINUM®: The premium brand for photovoltaic inverters

Eco-electricity and happy hens.
Environment in two important projects:
an open field PV plant combined with
a free-range poultry farm.
PLATINUM® supplied 174 inverters (model: 7200 TL)

PLATINUM® inverter manufacturing plant

The champion of its class –
the PLATINUM® R3 inverter

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Phone: +49 (0)7522 73-700
Fax: +49 (0)7522 73-710
platinum@diehl-controls.com
www.platinum-nes.com
90 employees

The PLATINUM® brand offers outstanding inverter technology at the highest level of performance. The patented DIVE® technology, SiC components and RAC-MPP®, which quickly finds the optimum working point, make PLATINUM® inverters one of the best of their kind with a peak efficiency of more than 98%. Thanks to the innovative DUAL-X® technology, the latest model – the PLATINUM® R3 – even achieves a peak efficiency of 98.4%, and is particularly low maintenance due to its pure convection cooling.
PLATINUM® offers string inverters in the power range of 2–22 kW to ensure it can provide the right solution for every system size. These inverters are manufactured in Wangen im Allgäu, Germany, to the highest industrial quality. The failure rate is particularly low due to intensive, six-stage quality testing, which ensures the robustness and reliability of PLATINUM® inverters. The result: totally robust and viable system components. The ten-year ex-works warranty and the option to extend it to 20 years for the majority of all products comes as standard with all PLATINUM® products.

In addition to inverters, the PLATINUM® product portfolio also comprises intelligent monitoring devices to monitor the power output of photovoltaic systems. PLATINUM® offers the WebMaster Home to optimize private consumption. It controls and visualizes any number of consumers, thereby allowing for intelligent energy management. PLATINUM® also supplements its system of high-quality solar technology with the PLATINUM® battery, which stores solar energy reliably and makes it available around the clock. PLATINUM® thus helps its users to achieve greater self-sufficiency in private power supplies and relieves the burden on national grids. The PLATINUM® battery is available in sizes ranging from Basic to XXL with a battery capacity of 4.6 kWh to 41 kWh and is compatible with all PLATINUM® photovoltaic systems or can be integrated into existing systems. PLATINUM® places emphasis on customer service as well as product quality. The company therefore runs regular training events for dealers, sales staff and installation engineers in its headquarters in Wangen im Allgäu.

Power-One: A World Leader in Energy Efficient Power Solutions

Power-One Italy S.p.A.

Ultra installation

Aurora Plus and Ultra inverters

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52028 Terranuova Bracciolini
Italy
Phone: +39 055 9195-1
sales.italy@power-one.com
www.power-one.com
Founded: 1973
Turnover: 1.02 billion USD (globally, FY 2012)
3,231 employees (2012, worldwide)

Power-One is the second largest designer and manufacturer of photovoltaic inverters worldwide. The company offers a diverse range of inverters to meet the needs of every installation – from residential applications to large-scale solar parks.

With 40 years of experience in the global power electronics industry, Power-One benefits from a unique level of expertise in terms of innovation, quality and service. Over the past four years, the company has continuously expanded its global footprint, setting up manufacturing, sales, service, and design facilities in Asia, Europe and North America. Power-One's aim is to continuously improve its market penetration and performance throughout the world.

While the demand for utility-scale solar parks is shifting to the emerging PV markets, Power-One is prepared to meet both the requirements of developed and emerging counties with its central inverter solutions. Its AURORA ULTRA central inverter family with an output of up to 1.5 MVA is one of the best solutions in its class, offering an innovative circuit topology, a passive liquid cooling system and a robust IP65 enclosure. Due to its modular design concept with an output of 690 V AC, the central inverter ensures easy installation and maintenance as well as maximum energy harvesting with an efficiency of up to 98.7%.

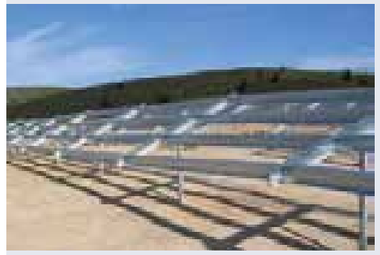
In order to also meet the future demands of large utilities, Power-One is constantly striving to improve its central inverters. The company is, for example, currently developing a novel voltage source inverter topology with additional grid services, which helps to increase the hosting capacity and stability of the grid. Moreover, Power-One is also looking into evolving markets, such as energy storage, and is using its long-standing experience to develop new best-in-class devices, helping to ensure our future energy supply.

Power-One also boasts one of the broadest portfolios in the inverter market for large-scale decentralized plants, offering three-phase string inverters ranging from 6 kW to 27.6 kW that guarantee high energy yields.

ArcelorMittal

Steel Structures & Foundations for PV Power Plants around the Globe

Magnelis®: The first metallic coating offering warranties against corrosion even on cut edges. 25-years warranty for solar applications.



Structure for a 5.6 MWp plant in a cyclonic region (La Réunion) under installation (top)

Ground-mounted structure for a 3.2 MWp plant in Spain (bottom)

PROFIL DU FUTUR: competitive and guaranteed structures for all soils and climatic conditions
Magnelis®: the first metallic coating offering corrosion protection even on cut edges in harsh environments
25-years warranty for solar applications

PROFIL DU FUTUR, a company belonging to the ArcelorMittal Group, is an expert in structural design and profiling for the construction market. Taking its industrial range of profiles as a basis (Multibeam, PSB, CE or U shaped), PROFIL DU FUTUR designs and manufactures structures for ground-mounted PV plants.
Foundation solutions are adapted to all soil types and use rammed or anchored poles depending on the ground's characteristics.

Each project is engineered on the basis of:
- single-pole or dual-pole structures
- climatic & geological conditions
- Eurocodes' static & dynamic calculations

PROFIL DU FUTUR offers short lead times thanks to an integrated supply chain and a dedicated engineering office.
PROFIL DU FUTUR works with approved installation partners.

Magnelis®
Magnelis® is an innovative zinc-aluminum-magnesium coating that offers protection in the harshest environments for solar racking and foundation systems.
- Superior against corrosion in comparison with other metallic coatings: Available in thicknesses of up to 6.0 mm, Magnelis® offers ultimate corrosion resistance in aggressive environments that is far superior to that of other metallic coatings thanks to the addition of 3% magnesium.
- Superior edge protection: Magnesium & aluminum elements combined in the coating layer create a thin protective film that protects cut edges from corrosion.
- Excellent workability: Folding, drawing or punching.

ArcelorMittal: your partner around the world
From products to tailor-made solutions, the ArcelorMittal Group is a global partner for all PV projects, thanks to its Flat Carbon Europe and Distribution & Solutions divisions, its International Construction Project teams & agencies network.

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www.arcelormittal.com/profildufutur
www.arcelormittal.com/industry/Magnelis
Founded: 2006 (ArcelorMittal Group)
Approx. 260,000 employees (Group)

Schneider Electric

The Global Specialist in Energy Management

Les Mees2, 10 MW power plant installation in France

Schneider Electric provides complete solutions from PV panel output to grid connection, including monitoring and control, as well as operation and maintenance services.

With 40+ years of experience in power conversion design and manufacturing, Schneider Electric is a Fortune 500 company that has been in business for more than 175 years. We've been manufacturing solar inverters since 1999, ranking us among the longest suppliers of such solutions on the market. Our presence in over 100 countries enables us to offer best-in-class balance-of-system solutions that meet local standards and benefit from local service capabilities, practically anywhere in the world.

Our solutions include:
- PV Box, a pre-wired, factory-integrated power conversion substation that includes the new Conext Core XC three-phase grid tie inverters, DC combiner boxes, a LV/MV step-up transformer and a medium-voltage switchgear.
- Conext Control, an intelligent and evolutive monitoring and control solution from string to grid.
- Array Box, a string combiner box installed between the PV modules and the inverter.
- Customized grid-tie substations enabling an efficient connection to the electric grid.

Schneider Electric products are present at every step of the power conversion chain, helping customers get the most efficient solar harvest from their installations thanks to qualified and reliable integrated solutions.

For more information about Schneider Electric and renewable energy solutions, please visit www.schneider-electric.com/solar

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Fax: +33 141 297-100
www.schneider-electric.com/solar
Founded: 1836
Turnover: 24 billion euros (2012)
140,000 employees

skytron® energy GmbH

OUR INNOVATION FOR YOUR BENEFIT

PVGuard® supervision platform –
quick overview of all plants and comparison
of important real-time data (left)

ArrayGuard® FH combiner box
with single PV string protection,
which monitors string currents at 100 ms

ArrayGuard® FH fuse holders for easy-to-handle fuse replacement – fuses on each single PV string

How long does it take to find a coin on a football pitch? Even on a surface area of several football pitches, you should lose neither time nor money.
With skytron® energy – Protected investments. Secured yields. Maximized profits.

How can our energy generation be shaped in a sustainable and profitable way? Providing the answers to this question has been the constant focus of all our operations for 36 years, ever since graduates from the Technical University of Berlin founded the Wuseltronik collective at the end of the 1970s and developed their initial visions for the systematic and cost-efficient use of renewable energy.

The pioneering spirit of those days is very much alive at the present-day headquarters of skytron® energy in the Berlin-Adlershof Science and Technology Park. Then as now, we consider working closely with scientific research as well as focusing on practical solutions to be essential in this fast-growing industry.

Our long-term experience ensures reliable plant monitoring at PV power plants throughout the world. Our power plant control technology and control room software now permanently watch over more than 3.7 GWp of installed PV output. We customize each installation to match the configuration of every individual plant – from precise string-current measurements right through to the control room presentation, thus allowing for effective supervision of your remote assets. Moreover, skytron® energy provides a complete O&M solution.

Our system is compatible with all standard inverters on the market, allowing it to be readily adapted to fit your facilities – and to expand with them. In this way your investment costs are protected and the cost-effectiveness of your plant is maintained.

The visions of the early days have been transformed into cutting-edge components for PV power plants in the MW sector, which are exactly what the market is looking for. Ensuring your success is at the heart of what we do.

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www.skytron-energy.com
Founded: 1977
86 employees

SMA Solar Technology AG

SMA Solar Technology – Energy that Changes

Reliable first-class quality: SMA system solutions for utility-scale PV power plants

Inverters are the control centers
of every PV power plant.

Unique worldwide: SMA Test Center for central inverters with a climatic chamber for extreme scenarios

The SMA Group is the world market leader in solar inverters and an energy management group that provides innovative key technologies for future power supply systems.

More than 30 years of experience and PV power plant projects in the megawatt range in more than 30 countries show our outstanding PV system expertise. SMA employs more than 5,000 people and maintains 90 service stations worldwide. 1,000 dedicated PV experts in R&D work daily on the optimization and development of new products and technologies.

PV power plants are optimally equipped with powerful outdoor devices from the Sunny Central CP XT inverter series. With an efficiency of 98%, the Sunny Central 900CP XT is the most efficient representative of this family. The SMA Transformer Compact Stations, including PV optimized transformers conforming to the international IEC standard, are ready for global application. As a turnkey medium-voltage solution, the SMA Transformer Compact Station can be used for all global voltage levels and enables flexible project planning and fast project kickoffs.

As a pioneer in grid integration, SMA offers tailor-made solutions worldwide that fulfill the rising demands of PV power plants. With their outstanding functions, SMA inverters play a central role in guaranteeing grid stability and actively managing PV power plants.

In addition to highest efficiency and low on-site consumption, SMA central inverters are designed for extreme environmental conditions. Only inverters with excellent technical properties, which operate in a smooth and uninterrupted manner over a long period of time, will guarantee the long-term success of PV projects in the sunbelt and climatically challenging regions of the world.

Large-scale PV power plants continue to present attractive long-term investment opportunities to investors, power plant operators and banks. To realize stable cash-flows of such projects, SMA central inverters as the core components of every PV power plant, secure maximum energy output and financial yields.

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www.SMA.de
Founded: 1981
Turnover: 1.5 billion euros
> 5,000 employees

Swiss quality by Sputnik Engineering

SolarMax inverters ensure high yields in PV power plants worldwide.

SolarMax supports clients during planning and commissioning as well as throughout the plant's entire life cycle.

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Fax: +41 32 346 56 09
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www.solarmax.com
Founded: 1991
360 employees (2012)

With its SolarMax brand, the Swiss company Sputnik Engineering AG has been using solar power for more than 20 years. SolarMax is making a valuable contribution to protecting the environment and generating renewable energy, thanks to highly efficient Swiss quality inverters. Regardless of whether the PV plant is realized with central or string inverters, the high performance and reliability of SolarMax products ensures high yields year after year.

Today the company ranks as one of the leaders in the international market for grid-connected solar inverters and has made a crucial contribution to the success of solar energy utilization. And because SolarMax thinks and acts in terms of sustainability, it is already seeking tomorrow's solutions today.

SolarMax has much expertise when it comes to large projects and has already overseen a large number of multi-MW projects around the world. SolarMax inverter and data communication products continue to meet increasingly more demanding grid requirements and make a huge contribution to grid

stability. Inverters significantly influence each PV plant's Levelized Costs of Energy (LCoE) in many ways. With this in mind, SolarMax develops high-efficiency inverter solutions with outstanding uptimes and long maintenance cycles. The flexible products and services meet investors' specific requirements and fulfill challenging performance ratio requirements.

With long-standing experience, the company is a competent and reliable partner for utility-scale projects all over the world. Clients will be supported with assistance and advice during planning and commissioning as well as throughout the plant's entire life cycle.

state-of-the-art technology you can trust

Solar plant in Biederbach/Germany (left)
SunPark® in Cincinnati/USA (top right)
Roof-top installation in Orlando/USA (bottom right)

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service@solarworld.de
www.solarworld.com
Founded: 1988
Approx. 3,300 employees (worldwide)

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The SolarWorld AG Group is a leading provider of quality solar power technology. We cover the entire value chain, from manufacturing crystalline solar modules to providing PV systems. Our core business is the manufacturing of crystalline solar modules and providing PV system solutions, which are sold through our strong distribution network. Through our 100% subsidiary Solarparc AG we can deliver utility-scale turnkey PV parks including project finance and full-service O&M.

SolarWorld delivers real solutions

At SolarWorld, we make the most of available space to generate clean energy. Our range of turnkey solutions includes everything from sophisticated rooftop installations to utility-scale, ground-mounted PV systems. SolarWorld's superior quality design ensures the highest energy yields and performance.

You can be sure to achieve the best possible return, no matter whether you invest in SolarWorld modules, balance of plant, turnkey solutions or full EPC service. With our expertly installed high-performance modules, you will enjoy exceptional yields and returns.

We also provide customized mounting structures for all kinds of solar applications, using high-quality core materials such as aluminum and stainless steel to guarantee maximum stability and a long service life. Let us help you design your ideal solution.

Powering the future

By placing your trust in SolarWorld, you are forming a partnership with an experienced and well-respected company, thereby laying a solid foundation for your investment. We will draft a detailed site plan and shading analysis for your project to calculate your potential yield. Sunny prospects are guaranteed for operators and investors alike, thanks to our professional system design services, which are essential for determining a system's cost-effectiveness and operational reliability. Our sales representatives and certified specialist partners will ensure you enjoy one of the best customer supports that Germany has to offer. SolarWorld is also active across the globe, with locations in France, Spain, the USA, Africa and Asia. Because after all, high-performance solar technology always pays off, no matter where you are in the world.

PV Inverters – Built for the Real World

Our utility-scale inverters power utility-scale installations in North America.

Our PVI 50-100KW inverters maintain the highest CEC efficiences.

Solectria Renewables' SGI 500XT

Solectria Renewables is a leading USA-based grid-tied PV inverter manufacturer. Our versatile, high-efficiency products provide solutions from 1 kW systems to multi-megawatt solar farms. Our products are backed by over 20 years of power electronics and inverter experience, and are supported by world-class warranties. All of our commercial and utility-scale inverters are manufactured in the USA, are ARRA and Ontario FIT Content compliant, and listed to UL 1741/IEEE 1547.

Industry leading technology

Solectria inverters offer best-in-class efficiencies to maximize production and ROI. Our inverters are customizable and offer a variety of options, such as integrated DC breakers, that result in flexible and cost-effective system designs.

Reliable performance

Solectria inverters are built to last for the lifetime of your power plant, providing high performance in any climate. Our unique inverter architecture minimizes hardware complexity and points of failure, resulting in high levels of uptime and simplifying field service and O&M.

World-class service and support

All Solectria inverters come with a standard five- or ten-year warranty that can be extended to 20 years; optional PM plans and 99% uptime guarantees are available. Our customer service department is available 24/7/365 and is staffed by a highly technical, qualified team.

Product line at a glance:

- MSS 1–2 MW: Megawatt Solar Stations, utility-scale directly to medium-voltage solution, including 1–4 SGI inverters
- SGI 500XT: SMARTGRID 500 kW utility-scale, external transformer inverter, 98% CEC efficiency
- SGI 225–500: SMARTGRID inverters, 225–500 kW, 97.5% CEC efficiency
- PVI 10–100KW: commercial inverters, 10–100 kW, configuration options
- PVI 1800–7500: single-phase residential inverters, 1.8–7.5 kW
- String combiners: optional DC disconnectors, surge arrestors, positive grounding and stainless steel or fiberglass enclosures
- SolrenView web-based monitoring: inverter direct, revenue grade, sub-array, agency reporting, XML feed, weather and cellular options

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Founded: 2005
175 employees

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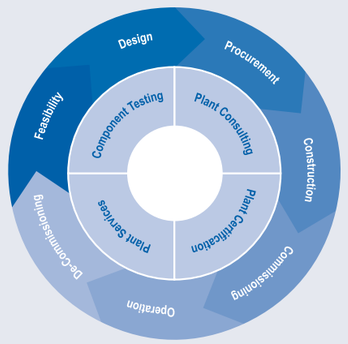

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19,000 employees

TÜV SÜD was established in Germany more than 145 years ago with the aim of protecting people, the environment and property against the possible adverse effects of technology. Today, the company provides testing, certification, inspection and training services to a myriad of industries. Our world class expertise allows us to help our business partners to manage risk and deliver confidence to end consumers via a network of 19,000 employees across 600 locations worldwide.

Clients can rely on TÜV SÜD's multidisciplinary approach and complete solutions, which cover the whole value chain from the manufacturing of modules and components through the investment process to operation and decommissioning. TÜV SÜD provides in-depth knowledge and experience to help clients manage risk, assuring that their business operations will run at optimized performance and maximum efficiency.

TÜV SÜD provides a range of assessment, inspection and certification services for PV investors, developers, EPC contractors, operators, manufacturers and importers. Our Certification Marks or expert reports adhere to local and global safety and performance requirements.

Our experienced inspectors monitor and examine the supply chain of components during pre-shipment and post-shipment inspections. They evaluate the bankability of both the products and the proposed facilities. Aspects of our assessment and inspection services may include initial site assessment, feasibility studies, energy yield evaluation, technical due diligence, construction and financial monitoring, monitoring of the yearly energy production and performance ratio evaluation, and diagnostics of malfunctions. Investors can depend on our expert opinion with regards to the reliability and feasibility of design and network compatibility. TÜV SÜD experts also advise clients on complex engineering solutions for integrating PV elements into buildings (BIPV). Additionally, TÜV SÜD is able to support clients with training and management system certification services.

Publishers

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Solarpraxis AG

Engineering, Conferences and Publishing for Renewable Energy

B2B magazines and industry guides:
The publication range of Solarpraxis includes the complete spectrum of renewable energy.

The engineering department generates up-to-date knowledge.

Solarpraxis conferences:
valued industry platforms

Solarpraxis AG is one of the leading knowledge service providers in the renewable energy sector. Since 1998 the Berlin-based company has been providing clients with expertise and professional service in the fields of engineering, conference organization and publishing.

Engineering

The engineering division generates up-to-date knowledge, which is then prepared for and presented to manufacturers, wholesalers, planners and trade professionals in a targeted, project-specific manner. Whether in the area of photovoltaics, solar thermal technology, heat pumps or pellets, clients receive expert and reliable support for reporting, large-scale solar projects, technical documentation, training, expert hotlines and customer service.

Conferences

The conference division focuses on organizing high-quality industry events for decision-makers both in Germany and abroad. These events are substantiated, relevant to the market and customer-oriented. Using specialist lectures and topical panel discussions, the division provides practical knowledge on market performance, finance and politics. The events are organized in Europe, Asia, North America and in the Middle East.

Publishing

The third and final component of the company's service portfolio is its publishing department, which boasts two international brands, "pv magazine" and RENI | Renewables Insight.

Since its initial publication in 2008, "pv magazine" has evolved into the top international photovoltaics magazine for decision-makers. With a global, Chinese and German edition, "pv magazine" is expanding its position as a knowledge provider. The media portfolio includes print magazines, e-papers, websites and daily newsletters.

The multilingual industry reports under RENI | Renewables Insight respond to the demand for high-quality industry and technology guides. In collaboration with professional associations, information on technology and markets is provided and companies are given an opportunity to communicate expert knowledge about their products and services.

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Founded: 1998
Turnover: 6 million euros
70 employees

Sunbeam Communications

Communications for the European Renewable Energy Market

Sunbeam combines high-quality communication services with expertise in technologies and markets in the field of renewables.

As a full-service partner we support you in managing your cross-media communications.

Sunbeam offers technically oriented communication services perfectly tailored to the dynamic environment of the European renewable energy market.

Since 1998, Sunbeam has been providing in-depth market knowledge and excellent contacts with industry associations and the media. We offer our expertise in the following domain areas:

Communications

With over fifteen years of experience in renewable energy, Sunbeam has acquired expertise in all relevant technologies as well as an extensive media network in the field. The company has successfully conducted a variety of campaigns for governmental departments and offers a wide spectrum of services to corporate clients, ranging from PR concepts and consultancy to the complete management of all press contacts.

New media

Sunbeam is one of the leading German agencies for information-oriented, accessible websites. The agency has won a prestigious BIENE award and ranks top in relevant listings for the content management system TYPO3. Two team members are also the authors of renowned specialist books on the design and implementation of web presentations.

Design

Sunbeam values visual communications as a key success factor in the renewable energy market, and thus offers comprehensive expertise in presenting complex matters to technically oriented target groups. In our work for companies, associations and governmental departments we specialize in editorial design for periodical magazines, high-quality brochures and extensive industry guides.

Added value

Sunbeam operates through all media channels connected to public relations, new media and design. Clients benefit from our experience both in the management of individual formats and the creation of integrated marketing solutions. Examples of this cross-media approach include our widely distributed press reports on solar, wind and bioenergy ("PresseTrend") and various services for print to web and/or social media publishing.

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Photovoltaics is becoming increasingly inexpensive. In contrast, the prices for electricity from conventional power plants are climbing. This is making the solar farm market segment progressively more lucrative for financially strong investors. Photovoltaics offers a profitable, long-term investment with comparatively low risk.

"PV Power Plants" is the first industry guide to focus exclusively on utility-scale solar power plants, and is aimed at system integrators, distributors, project developers, top planners and investors. Besides corporate portraits, it includes an overview of international market conditions and developments in technology, and depicts crucial issues related to planning and financing.

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