# Chances in PV Power

## Guide to PV Industry

Cover images

**Front**
100 MW Perovo Solar Park, Crimea (Ukraine)

**Back**
40 MW Waldpolenz Energy Park, Waldpolenz (Germany)

# Chances inPV Power 2012

## Guide to PV Industry

"Through targeted participating interests energykonzept has the bundled competancy to make a qualified contribution to meeting global energy requirements with the planning, realization, and financing of international renewable energy projects." CEO B. Bolsenkoetter

# Pressure on Prices and Innovations

**By Bodo Bolsenkoetter,**
**CEO of energykonzept.de**
**by Hallertauer Leasing GmbH**

**Dear Readers,**

**Today's PV market is now completely different to that of one year ago when the previous edition of this brochure was published. Thanks to a dramatic fall in the price of solar modules and an equally significant drop in the price of inverters and other components, solar power is now economically viable in many new areas. Grid parity, which has for a long time been a crucial hurdle to cross in terms of market development, has been achieved far more quickly than expected in many countries.**

Additionally, PV solar power is now so much cheaper than electricity from concentrated solar power (CSP) plants that the future of these plants is being brought into question before the technology has even gained a strong foothold. At the same time, international technology introduction programs and market distribution have changed dramatically. While in Europe almost all feed-in tariff (FIT) programs have been significantly reduced, or as is the case in Spain, completely suspended, many countries worldwide have created or adapted market launch programs, meaning that an ever-rising number of countries are installing a continuously higher amount of solar power systems.

Germany was for a long time a step ahead in terms of system prices, but now at least the Chinese have caught up, and it seems that further countries will soon be following suit. In addition to increased efficiency in terms of implementation, the extremely diverse wages play an important role in this. It is usually the case that in countries which have created stable legal conditions for implementing photovoltaics, system prices fall very rapidly in line with the development of the supply chain.

However, there are great regional variations, an issue which, among others, we want to tackle in this brochure, by striving for international transparency in terms of prices and technology. In doing so, we hope to make solar electricity, which in many countries is already available at significantly less than 10 euro cents per kilowatt hour (kWh) (thanks to regulations ensuring the best system prices), even cheaper. Different forecasts suggest that prices between 2 and 3 cents/kWh will be possible in the most suitable locations around the world by 2020 at the latest, making it possible for the market volume to expand significantly. As a result, it has been predicted that an annual worldwide installation of 200 gigawatts peak (GWp) or more is likely.

Even today, solar electricity is lowering Germany's peak load power prices dramatically. On certain days, the currently installed capacity of more than 25 GWp leads to electricity prices of zero at the German Energy Exchange, and even during the winter of 2011/2012, solar power produced in Germany was exported to France to counterbalance an electricity shortage. Despite eight nuclear power stations being disconnected during 2011, Germany has remained a net exporter of electricity and market prices in the day are significantly lower than power prices before the nuclear plants were shut down. This is all thanks to solar power.

It is clear that PV power generation lost its image as being "too expensive" at an impressive speed, and it is now seen as the power production technology which is the quickest to install and the most low-maintenance, while also being among the cheapest. It has achieved all this without consuming resources and only produces very low levels of $CO_2$.

Climate protection and a lower level of dependency on imported raw materials, thanks to the flexibility and stability of the technology, are an added bonus, and form yet another incentive for further developing this technology rapidly worldwide.

Bodo Bolsenkoetter


Industry

# Heading for New Dimensions

The solar power station in Senftenberg (Germany) has a total output capacity of 148 MW – enough electricity for around 50,000 homes.

## Increasing importance of large photovoltaic plants

Solar plants are increasingly moving into a range which has traditionally been the domain of classic large-scale power plants. In 2008, the solar farm constructed in Brandis, south of Leipzig, set a new record with an output of 40 megawatts (MW). 2009 then saw a solar power plant constructed in Ontario with a peak output of 80 MW. A 290 MW solar farm is being connected to the grid in Arizona in 2012, and the world's first solar power plant with an output of 550 MW is due to be commissioned in California in 2013. Photovoltaic power plants are thus achieving scales equal to those of conventional coal-fired power stations. In Asia there is even talk of gigawatt (GW) power plants, which have so far been the preserve of the nuclear industry.

According to data from the European Photovoltaic Industry Association EPIA, approximately 29.7 GW of solar power were connected to the grid in 2011 – around 40 percent more than the previous year. With the exception of plants in Europe and Japan, this rapid expansion of capacity is chiefly being achieved through large solar power stations with MW-scale outputs.

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. Plant costs have fallen since 2009, though it is chiefly solar modules that have become noticeably cheaper.

And the prices of inverters are also in decline, with a drop of 15 percent calculated by market research company IMS Research. Photovoltaics is becoming increasingly inexpensive, a development that is fuelling the boom in solar power plants and smaller-scale rooftop systems alike. 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 – even despite tumbling feed-in tariffs. Photovoltaics offers a profitable, long-term investment with comparatively low risk.

The 5 MW power plant near the Greek city of Drama has a projected annual output of 7,100 MWh.

**Top 15 markets 2011 worldwide**

| | COUNTRY | 2011 NEWLY CONNECTED CAPACITY (MW) | 2011 CUMULATIVE INSTALLED CAPACITY (MW) |
|---|---|---|---|
| 1 | Italy | 9,284 | 12,754 |
| 2 | Germany | 7,485 | 24,678 |
| 3 | China | 2,200 | 3,093 |
| 4 | USA | 1,855 | 4,383 |
| 5 | France | 1,671 | 2,659 |
| 6 | Japan | 1,296 | 4,914 |
| 7 | Belgium | 974 | 2,018 |
| 8 | Australia | 774 | 1,298 |
| 9 | United Kingdom | 784 | 875 |
| 10 | Greece | 426 | 631 |
| 11 | Spain | 372 | 4,400 |
| 12 | Canada | 364 | 563 |
| 13 | Slovakia | 321 | 468 |
| 14 | India | 300 | 461 |
| 15 | Ukraine | 188 | 190 |
| | Rest of the World | 1,371 | 6,299 |
| | Total | 29,665 | 69,684 |

Source: EPIA

## Economic viability the deciding factor

Project planning and management, installation and the operation of large PV power plants present new challenges for 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.

We must also bear in mind that countries such as Germany and Italy are slashing government incentives for solar power (feed-in tariffs). As a result, the photovoltaics power plant market is increasingly playing by the economic rules of the power generation market. The Levelized Cost of Energy (LCOE) therefore decides whether or not an investment in a solar power plant will pay off. 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.

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 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 summer days. At the European Energy Exchange in Leipzig, the falling procurement costs for solar power are striking since, because its yield curve correlates closely to peak demand, it curbs the cost of peak power.

Although solar power generation has not yet reached true profitability, the costs are steadily falling and investment in photovoltaics is rapidly increasing – particularly in installations where grid parity is tangibly close or has even been achieved. This trend was observed worldwide during 2011 and is likely to continue in 2012. By the end of 2011 it was possible to install a 550 kW solar generator for one million euros. Protecting such investments is of critical significance. Precise analysis of all technical, financial, tax-related and legal details is therefore required to ensure the success of a solar project.

Size is not the only thing that counts, however – speed plays a big role, too: Plants with large outputs of 100 MW and above can be 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 2012, a 100 MW solar farm at Perovo on the Ukrainian Crimea Peninsula was put into operation.

Connection to the grid presents a particular challenge, since the dramatic expansion of photovoltaics is increasingly creating bottlenecks in the power grids. Restructuring these to accommodate distributed energy supply is a matter of the highest priority. Large solar installations usually feed into the medium-voltage grid, though making feed-in points accessible can sometimes incur considerable costs. The Medium Voltage Directive (Mittelspannungsrichtlinie) issued by the German Association of Energy and Water Industries (BDEW) regulates feed-in in Germany and contains special stipulations on how inverters should function. For instance, it must be possible for grid operators to control them in order to disconnect the plant in the event of grid fluctuations. Solar power plants must therefore obtain corresponding certification for their feed-in management systems.

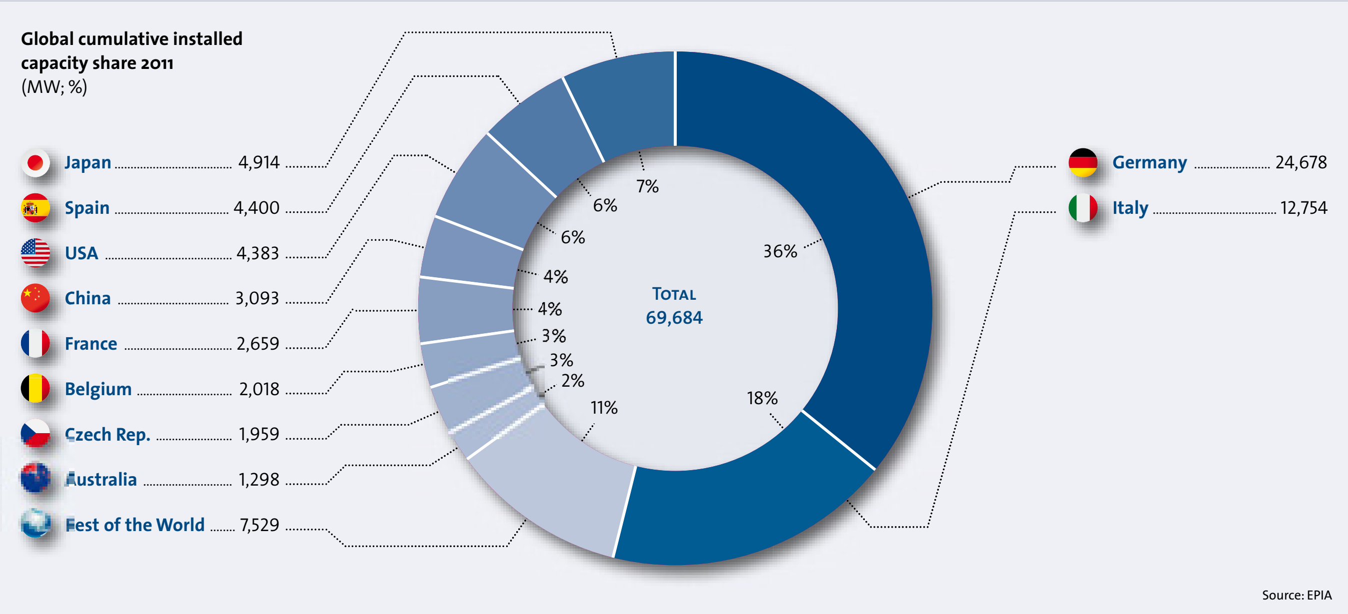
Hybrid power plants that generate both solar and wind power from the same area are drawing ever more attention. Here, the costs of purchasing and developing the land are only incurred once, as are those for the medium-voltage switchgear (transformers, feed-in point). Solar power is generated throughout 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. Additionally, it is not usually necessary to expand the grid, since the combination of solar modules and wind turbines will only exceed the full grid capacity for very short, rare periods of the year.

### Rising demand

In the summer of 2012, the German government made drastic cuts to the feed-in tariff for large-scale power plants. Henceforth, plants with outputs between 1 and 10 MW will receive remuneration of just 13.5 euro cents per kilowatt hour (kWh). Solar installations with a rated capacity of over 10 MW will receive absolutely no statutorily regulated remuneration. (As the legistlative process is in the course of being completed in 2012, these regulations may be subject to change.)

Countries including Italy, France, Great Britain and Spain are following suit and subsidizing large-scale plants less and less. On the other hand, a growing number of communities and companies want to gain independence from the high electricity prices charged by conventional suppliers. They can lower their procurement costs by using large industrial roofs or communal areas to install photovoltaics.

112,000 solar modules with a peak capacity of 31 MWp were installed on a plateau near the French Alps, at the Les Mées solar farm.




But 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 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 China's government is 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.

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 competitive in this market, the costs will certainly have to drop a great deal further.

### Market segments

In principle, three key photovoltaics market segments can be distinguished: "Residential PV" 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 are described as "utility-scale" plants. They are subject to the regulations on power plant construction.

Left: The Blythe Solar Project (California), one of the first utility-scale PV projects in the United States.

Right: On 140 acres of unused land on Nellis Air Force Base, Nevada (USA), 70,000 solar panels will generate 15 megawatts of solar power by using a solar tracking system.

# National Markets

## PV power plants, the fastest growing sector

The Finsterwalde solar farm is situated near the former brown coal mine of Klettwitz-Nord in Germany. It has a peak output of 80.7 MWp.

In 2011, 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 small roof-mounted installations, expansion in Asia, North America and other regions has almost exclusively stemmed from large installations within the utility-scale sector.

According to figures from EPIA, 29.7 GW of new installations were added in 2011, with 21 GW in Europe alone. Analysts at NPD Solarbuzz predict that emerging markets, such as China, North America and India, will also grow further in 2012, accounting for around a third of new PV capacity installed worldwide. In 2011, they were responsible for one fifth. Europe's share will shrink to just over half in 2012, dropping to under 42 percent by 2016.

The soil at the location of the 1.48 MW solar power plant near Velký Týnec in the Czech Republic was completely renaturalized when the plant was installed.

### Europe

In terms of global cumulative installed capacity, Europe still leads the way with more than 51 GW installed as of 2011. This represents about 75 percent of the world's total PV cumulative capacity. The European photovoltaics market is dominated by three countries: Italy, Germany and France. Together they accounted for 85 percent of the European market in 2011.

## Striving for increased efficiency

Owing to the relatively high efficiency of cristalline modules, compared with thin-film modules less installation area is needed per unit of output.

Until just a few years ago, solar plants were chiefly built from components that were often only available in limited quantities. 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 kilowatt hour of solar electricity, which competes with that of other technologies. Return on investment is therefore determined by the efficiency of the entire system, from individual modules to inverters and grid feed-in.

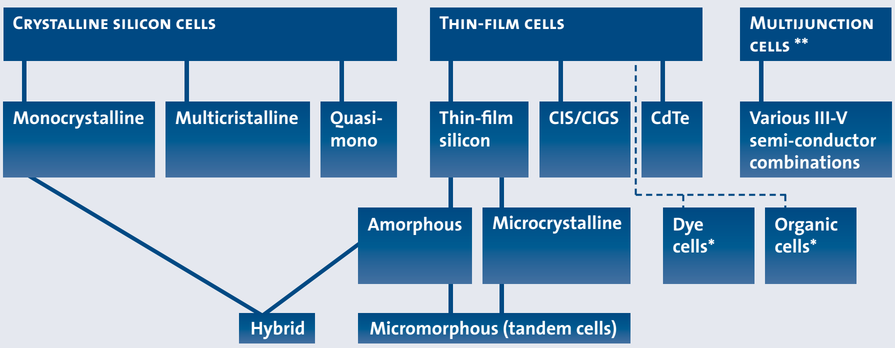
### Crystalline silicon or thin-film

Business in megawatt-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 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 "quasi-mono" wafers achieve similarly high efficiencies to monocrystalline solar cells thanks to the particularly cheap polycrystalline silicon wafers employed. Manufacturing costs are reduced even further in the string ribbon process, where 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 thick and eliminates the heavy material losses that ensue from sawing conventional silicon wafers, which are 180 micrometers thick. Tandem cells that combine crystalline wafers with amorphous silicon coatings achieve extremely high efficiencies despite the wafers being exceptionally thin.

As thin-film modules are significantly less efficient, 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, and the disadvantage of higher area requirements is disappearing as a result.

Since it is now possible to manufacture thin-film solar modules in large numbers,

**Types of solar cells**




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

Left and below: Solarpark Waldpolenz (Germany)

Below: Inverter housing: Inverters regulate solar voltage and solar power such that the solar generator will furnish the maximum possible output.

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.

As a result, large-scale PV plants equipped with thin-film modules can generally produce power just as cheaply as those constructed using crystalline modules. The lower manufacturing costs 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 first choice for 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 saw the market share of thin-film technology recede somewhat, 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 construction. 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.

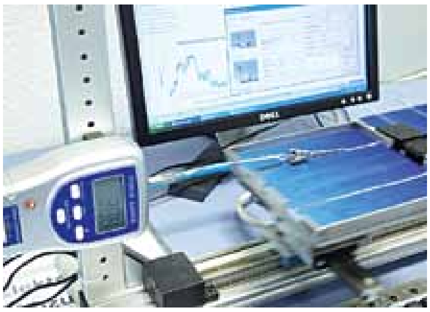
| CELL MATERIAL | MODULE EFFICIENCY | SURFACE AREA NEED FOR 1 KWP |
|---|---|---|
| Monocrystalline silicon | 13–19% | 5–8 m² |
| Polycrystalline silicon | 11–15% | 7–9 m² |
| Micromorphous tandem cell (a-Si/µc-Si) | 8–10% | 10–12 m² |
| Thin-film – copper-indium/gallium-sulfur/diselenide (CI/GS/Se) | 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.

### 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

Pull-off tests ensure that all connections on the module are safely soldered together.



A sun simulator insolates modules with light from a spectrum close to that of the sun under laboratory conditions. Shading can also be simulated.

**Process steps in quality control**

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

**Project development and planning**
- yield assessment
- inspection of details with respect to grids, site subsoil, shading etc.
- review and optimization of DC and AC planning

**Module quality control**
- precise module specification
- technical consulting
- factory inspections
- before shipment or after receipt:
  - high level of spot checks to assess performance (flash testing by an accredited test laboratory)
  - high level of electroluminescence sample imaging
  - destructive testing
- extra audit

**Quality control during construction and acceptance of work**
- construction management
- training for installers
- sample electrical measurements (output, characteristic curve, open-circuit voltage, short-circuit current)
- function testing and acceptance measurements (thermal imaging under load)
- test reports

**Prior to warranty expiry**
- visual check of entire installation
- thermal imaging under load

**Monitoring**
- string monitoring
- 365-day monitoring

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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 reach a temperature of 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. For the “PV+Test” (www.pvtest.de) introduced by Solarpraxis and TÜV Rheinland, on the other hand, samples are bought on the open market and the results published as high-score listings in the trade magazines “photovoltaik” and “pv magazine”, as well as at www.pvtest.de. Increasing importance is being attached to both testing for potential induced degradation (PID) and electroluminescence cell and module inspection, as these analyses reveal weak points in production and allow flaws to be detected fast.

In addition to these type 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

Left: An electroluminescence test reveals even the smallest module damage.

Right: Test for potential-induced degradation, one of the main causes of drops in the output of photovoltaic modules


The flash test measures the output performance of a solar PV module to ensure its operability.

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 equipped with just one specific module type. These modular units allow the solar plant output to be scaled up rapidly with the greatest of ease.

### Inverters

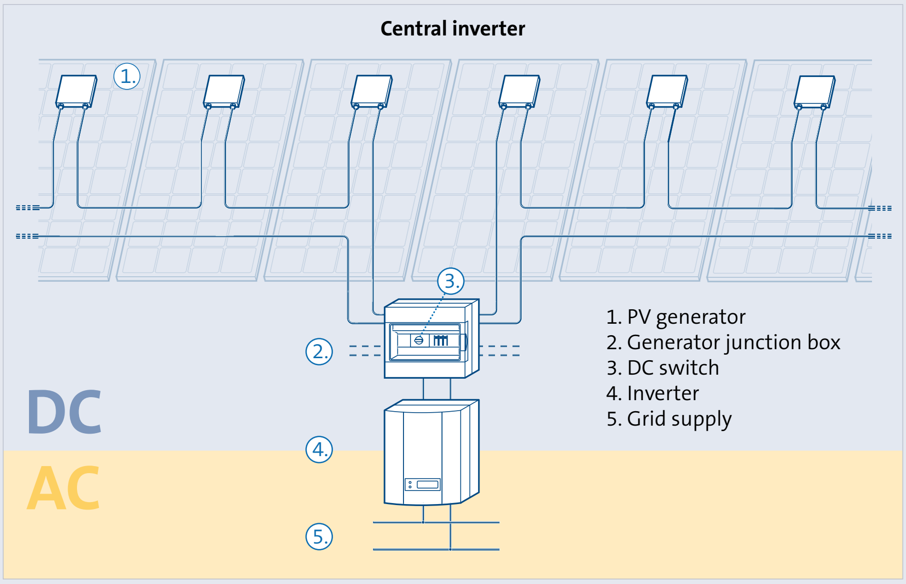
Solar generators are a combination of solar modules connected in series and in parallel: Depending on the voltage of a given solar module, up to 30 of them may be connected in series to form a string, so the electrical voltages of the individual modules will add up. Connecting 20 to 30 modules in series produces a string with a system voltage 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 me-

String inverters of a large PV plant

Installation of a central inverter




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

dium-voltage grid, which can have a voltage of between 20 and 50 kilovolts (kV), depending on the national grid standard in a given country.

Not all inverters are suitable for every type of module (DC voltage window, with or without transformer, with or without grounding of the DC circuit). It should therefore be checked when planning whether or not the inverter is approved for the chosen modules

### 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 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 be given to the system with the lowest energy generation costs.

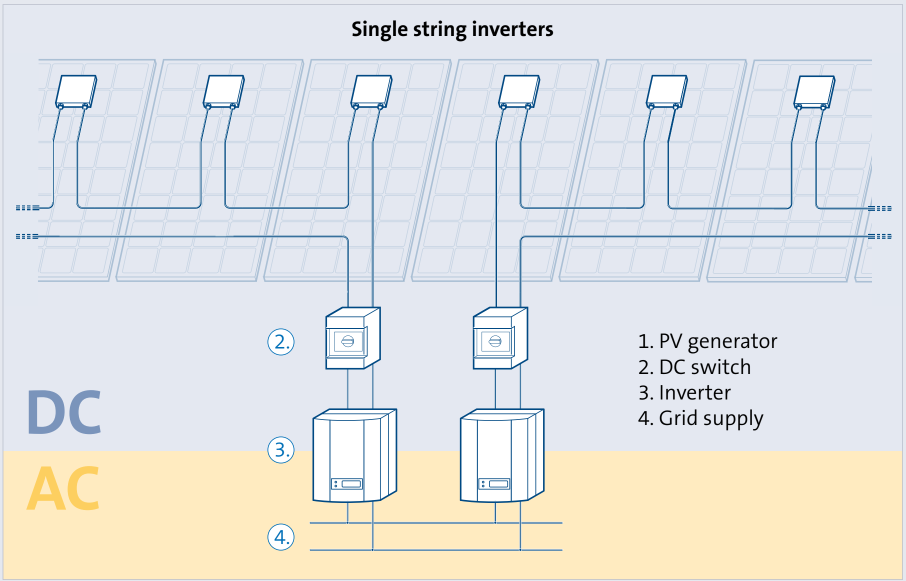
### Module Level Power Management

Of late, module level power management (MLPM) solutions have increasingly gained precedence. Known as power optimizers, they are intended 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. Long-term experience with these new technical solutions is yet to be gained, and it therefore remains open as to whether they will bring economic advantages.

An enhanced version of the power optimizer was recently launched onto the market as the Module Maximizer. This device not only tracks the MPP, it also records the output data of a module at

Left: Central inverter

Right: View inside a central inverter




Module inverters connect single modules or pairs of modules directly with the grid.

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.

### 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 the inverter should be adequately proportioned to allow peaks in insolation to be fully exploited without the device becoming overloaded. 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.

### 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 new directive on medium voltage grid feed, which came into force in Germany in April 2011, 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

### 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/m$^2$ 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/m$^2$ 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:

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

Left: To avoid energy losses, the cabling must be carefully designed.

Right: Modules are supported by systems made of wood, aluminum or steel.

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.

Permanent monitoring of plant operation is also 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.

Since 2012, 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 forcing the German Association of Energy and Water Industries (BDEW) and its partners to implement transitional provisions.

### Steady ground

Solar parks should reliably generate electricity for 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 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.

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.

### Secure anchoring

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". 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 the falling module prices.

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.

### Losses due to 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 is caused by 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

Industrial-scale batteries are needed to buffer peak power outputs from solar power plants. The two most commonly used types are redox flow and sodium sulfur batteries, though commercial use of these systems has not yet been adequately tested. Lead-acid and lithium-ion batteries are currently only supplied for small-scale systems, to optimize energy use in private households. 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. Here, surplus solar power is used to generate methane. This combustible gas is then used in conventional gas power plants 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 kilowatt hour 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.

# Financing

## PV becomes increasingly attractive for the finance industry

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

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 kilowatt hour. This not only includes the system costs, but also every bit of expenditure on realizing the solar project, the operating costs and financing.

In the past, the prime focus of photovoltaic business was on technical components. 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, while monocrystalline silicon parks with tracking systems sit toward the top. 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.

The Lüptitz citizens' solar power plant (Germany) is run by a cooperative of private persons.

Banks require the quality of the installation to be inspected by external experts.

## Opportunities for financing

Financing stands or falls with the actual annual solar power yield fed into the grid. 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 (2010 and 2011) and Italy (2011) 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.

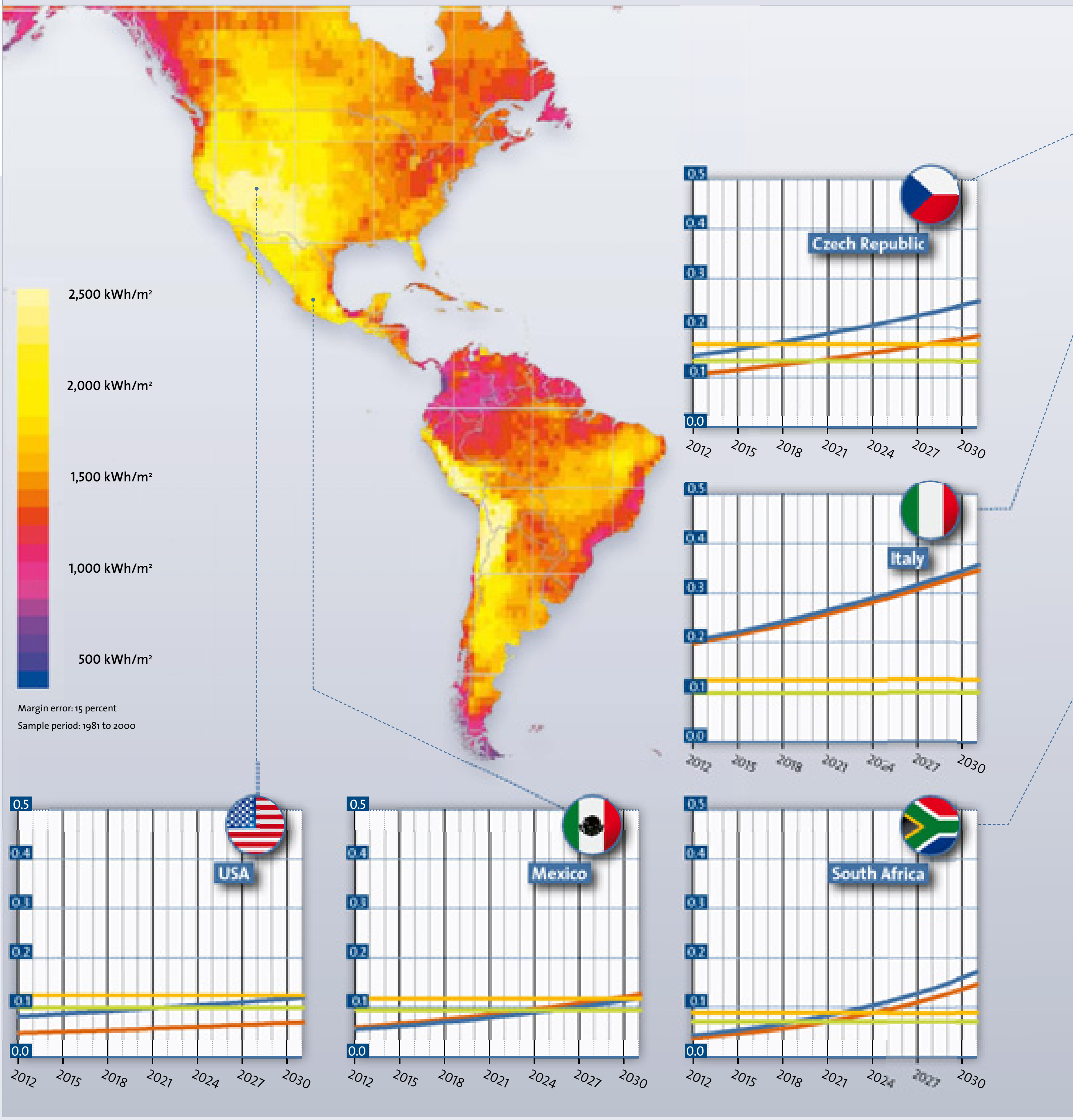
Thanks to the expansion of production capacities for modules and inverters across the globe, there are practically no further bottlenecks that could limit the growth of photovoltaics as an industry, and solar parks in particular. From now on, area and capital will be the critical factors. One consequence 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.

### Competence as General Contractor

"Through targeted participating interests, energykonzept has the bundeld competency to make a qualified contribution to meeting global energy requirements with the planing , realization, and financing of international solar projects."

CEO Bodo Bolsenkoetter

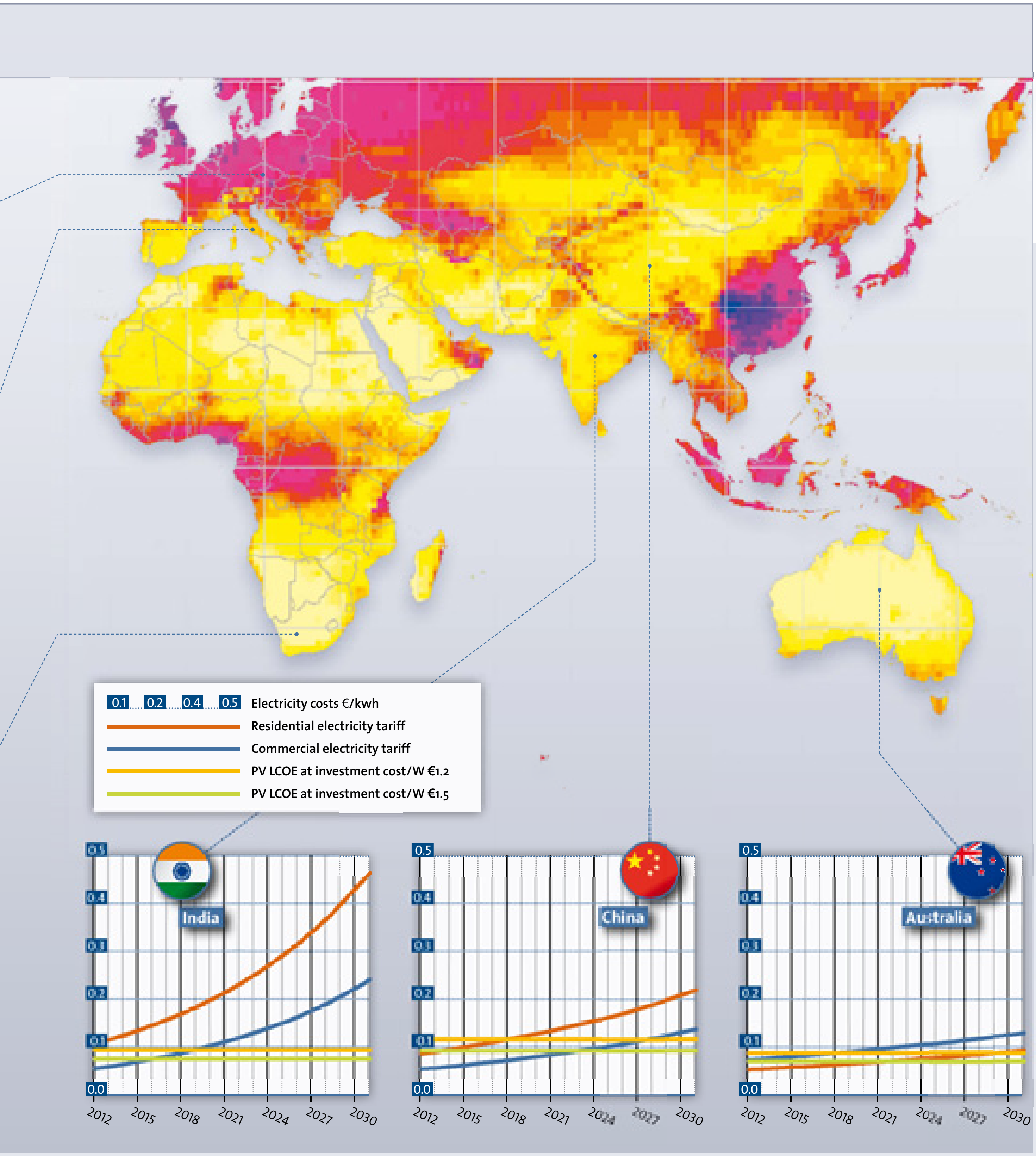
Annual global irradiation and solar electricity potential




**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 Levelized Cost of Energy (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 2011 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 mod-




Source: Meteonorm 6.0 (www.meteonorm.com)/Solarpraxis AG

ule prices, insolation at the site and plant lifetime. An academic paper on the importance of LCOE calculations for photovoltaic project developers and market stability was published in early 2011 in Energy and Environmental Science. The paper gives an insight into how photovoltaics would compete in the energy sector if LCOE calculations were applied to the cost side of the grid parity equation and then comparisons made between the actual electricity prices and those that are forecasted.

### 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

Left: The Helbra solar farm (Saxony-Anhalt, Germany) has a total output capacity of 11.7 MW.

Right: The PV plant is situated on a 18,000 m² property on the outskirts of the German town of Adorf and generates 1.2m kWh of electricity per year.

contracts), encumbrances, pledging of the operator's account or pledging of shares in the business. In the past, project financing was sometimes too tight, 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.

**RES-LEGAL**

The free RES-LEGAL database provides an overview of the manifold subsidization models in Europe and 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 within the EU. The collection of models for remuneration, tax incentives and certificates as well as grid access comprises 27 countries. A search assistant enables users to analyze and compare legislation in the different countries.

www.res-legal.eu

### Assessment may, for instance, follow these four steps:

**Legal due diligence**

This step examines 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**

Experts check 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.

**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, CCTV), 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.

### Estimating the yield of an investment (SPX Index)

The specific yield of an investment can easily be quantified using an empirical formula that illustrates the key operating parameters of the installation. This formula was devised by analysts at Solarpraxis AG in order to optimize plant configuration and the use of financial resources. If the specific yield of the plant is then multiplied by the availability of the inverter to the grid, this gives the total yield taking into account every euro spent.

### Political conditions in Europe

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

Left: The PV sound barrier is located on a motorway in Germany, close to Munich's airport, with a length of 1.2 km and a capacity of 500 kWp.

Right: The Reckahn Solar Park has a capacity of 37.7 MWp and is located in Reckahn, Southwest of Berlin, Germany.

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. 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. The picture outside of the EU is also quite diverse. 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 (Investment Tax Credits: ITC), and can reach up to 30 percent. These sums can be directly offset against tax liabilities, and if no tax is due, the ITCs 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. Power Purchase Agreements (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

The savage cuts to feed-in tariffs did nothing to dampen the photovoltaics boom in Germany during 2011. In March 2012, the German parliament voted in favor of drastically lowering the tariffs again from April 1, 2012. Now only three power classes remain: small rooftop systems with outputs up to 10 kW (19.5 euro cents per kWh), larger roof-mounted installations with outputs between 10 kW and 1 MW (16.5 euro cents) and plants with outputs of 1 to 10 MW installed on roofs or on the ground (13.5 euro cents). Starting in May, remuneration for solar power fed into the grid will be reduced by one percent every month. Operators of small installations will be required to consume 20 percent of the power they generate on site or to sell it independently. A figure of ten percent is required from medium-sized plants with an output of up to 1 MW. Although power from larger MW-scale installations is remunerated in full, very large plants with outputs over 10 MW no longer receive any remuneration whatsoever. Transitional provisions are in place for rooftop and ground-mounted plants that apply until the end of June 2012, and for redeveloped brownfield sites until late September 2012.

Furthermore, in future the outputs of all MW-scale plants within a four-kilometer radius of one another will be added together. If they are found to have a cumulative capacity of over 10 GW, these sub-generators will no longer receive remuneration, even if they belong to different owners. This rule will apply for an interim period of two years. And even the concept of commissioning a solar installation has been reformulated. In future, it will no longer be possible to put solar arrays into operation that do not have inverters. However, the connection to the grid will continue to have no impact on the feed-in tariff it receives.

(As the legistlative process is in the course of being completed in 2012, these regulations may be subject to change.)

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.

energykonzept.de
by Hallertauer Leasing GmbH
Hohenwarter Str. 68
Pfaffenhofen a.d. Ilm
Germany

www.energykonzept.com

Contact Mail : energykonzept@gmx.de