



CIS PowerModules by Solar Frontier

Highest yields – even under extreme conditions



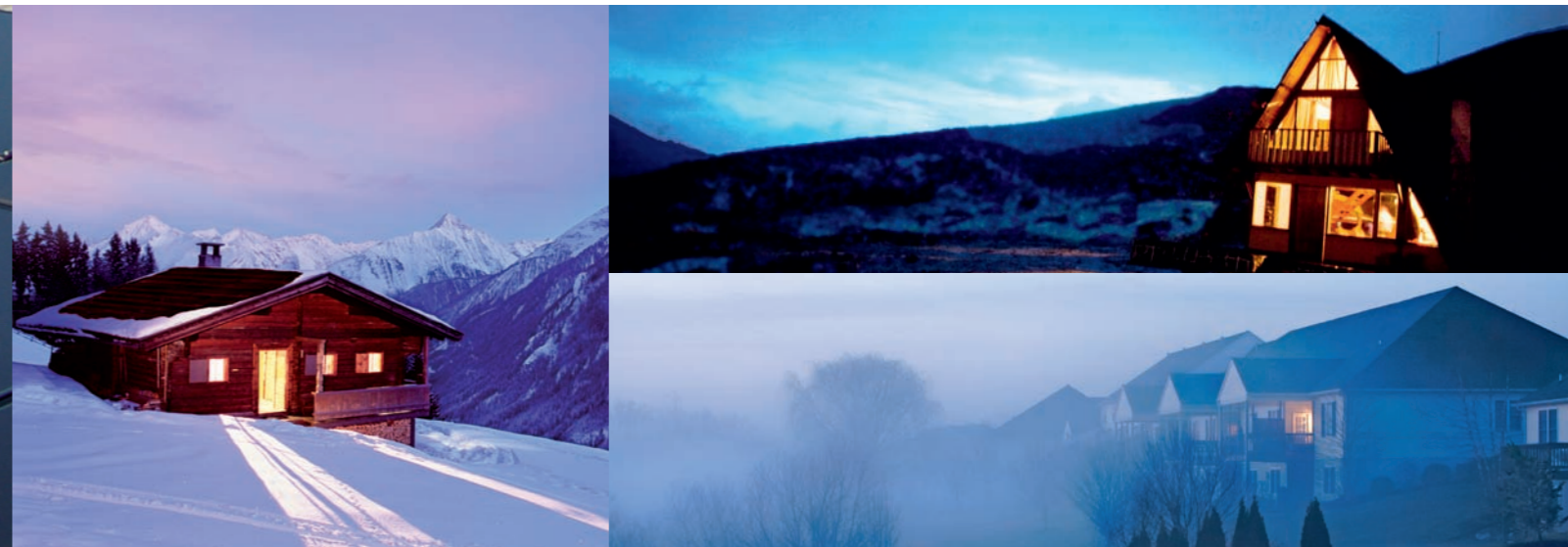
CIS Technology

Developed for highest yields.



External factors for PV yields

A matter of prevailing conditions.



The photovoltaic market offers a wide range of solar modules based on very diverse technologies.

The modules fall into the main categories of:

- Thin-film modules
- Crystalline modules based on silicon
- Organic modules
- HIT and tandem solar cells

Thin-film technology is the most innovative of these segments. But this field can be approached in a variety of different ways. One of them is the solution offered by CIS technology. Its name is derived from the elements copper (C), indium (I) and selenium (S).

Superior features.

A decisive advantage of CIS over conventional crystalline silicon resides in the higher output per installed watt-peak – resulting in a larger energy production of the installation. Their advantage over other thin-film modules (such as amorphous, micromorphous or tandem modules) lies in the higher efficiency. Aside from CIS, organic modules also hold great potential;

but this technology is currently years away from serial production.

What sets CIS apart not only from crystalline modules but also from other thin-film technologies such as cadmium-telluride is their outstanding environmental friendliness: CIS PowerModules by Solar Frontier are free of cadmium and lead, requiring no special recycling process. Therefore, they meet the stringent requirements of the RoHS guideline (Restriction of Hazardous Substances).

Added value throughout.

On the whole, the CIS technology developed by Solar Frontier offers a unique combination of advantageous features – not only for rooftop, but also for free-field installations:

- **greater efficiency & higher yields**
- **greater security**
- **greater environmental friendliness**
- **greater aesthetics**

Take a look at the added value of CIS PowerModules by Solar Frontier!

What criteria should an ideal photovoltaic installation meet to consistently produce the highest yields?

If you could select the criteria that the ideal rooftop installation should have to meet, you would probably choose an installation facing south on a roof tilted at an angle that is best suited for sunlight to strike in any season. The environs of this installation would be absolutely free of shade, the air always clear and devoid of impurities from dirt, dust, fog or smog. What's more, the weather would always be both sunny and cold because in addition to the above conditions, high solar radiation values and low temperatures offer the best premises for the highest yields.

In other words: An ideal PV installation will always be rare. That's because the real world is usually quite different. Roofs often face east or west. Trees, chimneys or nearby buildings cast shadows. Pollutants are in the air. The weather fluctuates between high tempera-

tures, fog or clouds. And every one of these factors reduces the yield.

The solution:
Highest yields - even under extreme conditions.

With CIS PowerModules by Solar Frontier.

This is precisely where the advantages of CIS technology come in. Thanks to their high shadow tolerance and their favorable low-light performance the CIS PowerModules by Solar Frontier offer the highest yields even under extreme conditions: with shadows, at high temperatures and low light. In addition, with what is called the light soaking effect they even offer additional yield results.

Greater efficiency: excellent low-light behavior



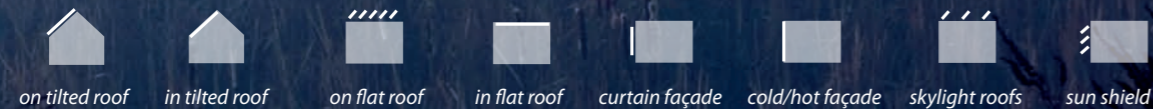
Highest yields – even with foggy outlook.

Mornings, evenings, fog, diffuse light, overcast skies – the sun rarely shines full force. And yet, it is precisely in the midst of these daily adversities that, thanks to their good low-light performance, the CIS PowerModules by Solar Frontier produce more power than others.

Due to their wide spectral sensitivity that is optimized to the luminous density of the sun, Solar Frontier modules generate more kilowatt hours even in weaker light conditions. Thanks to their sensitivity to red and infrared light, they get to work early, generating power in the early morning hours and continuing on into late in the evening; they can even convert the short-wave diffuse blue light during the day better than other technologies.

In practice, the good low-light performance of the CIS PowerModules means that the modules generate high yields even under conditions that are unfavorable for crystalline silicon modules. Even on east-west roofs, flat roofs or even roofs facing north, they achieve more operating hours and deliver more solar energy than any other module technology.

Fig. below: Mounting examples for PV installations with CIS PowerModules



Greater efficiency: high shadow tolerance

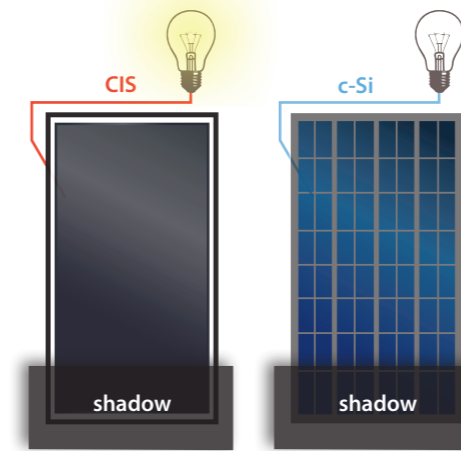


Highest yields – even in the shade.

Due to their high shadow tolerance, CIS thin-film modules are very efficient even when shadows are cast over the modules or the surfaces are partly covered up (for instance with leaves). The reason for this can be found in the different cellular structure. The square silicon cells in the module are connected in substrings. Contrary to this, the long and very narrow thin-film cells are connected in series. If in conventional silicon modules part of the surface is covered up, then not only one cell,

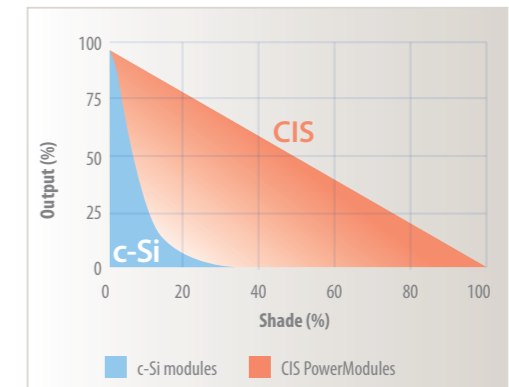
but the entire module shuts down. As opposed to this, CIS PowerModules are affected only in the covered area. This means higher yields even in the shade.

There is another advantage to this high shade tolerance: Rows of modules can be mounted closer together in free-field installations and on industrial flat roofs. This means that higher power yields can be achieved in limited spaces.



steady energy production in spite of shade

c-Si modules produce far less under the same conditions



CIS PowerModules produce steady energy due to their shade tolerance, even when part of the cell is shaded

Reference: Blandford, United Kingdom

The challenge: poor weather conditions, much rain

System capacity	41.4 kWp
Annual global irradiance	1,091 kWh/m ²
Average yearly temperature	10.7 °C
Annual precipitation	786.6 mm

Reference: Bottrop, Germany

The challenge: Partial afternoon shade

System capacity	42.75 kWp
Annual global irradiance	950 – 1,000 kWh/m ²
Average yearly temperature	9.6 °C
Annual precipitation	930 mm



Greater efficiency: high temperature stability

Highest yields – even in sweltering heat.

In all photovoltaic modules, output diminishes with increasing temperatures, which results in yield losses. This is why the performance of conventional technologies is considerably lower in the summer months or in hot regions, in spite of high sunshine values.

CIS PowerModules are less dependent on temperature than crystalline silicon modules and therefore exhibit greater temperature stability. This is reflected in a low temperature coefficient of the output, which is usually gi-

ven in percent per degree Kelvin (%/°K) in the technical data sheet. At an outside temperature in excess of 30° Celsius, solar modules exposed to the heat for hours at a time can reach temperatures of up to 70 °C.

Therefore, especially in the summer and in hot regions, the temperature stability of CIS PowerModules is a great advantage, which is reflected in a higher energy production of over 10% compared to crystalline modules.

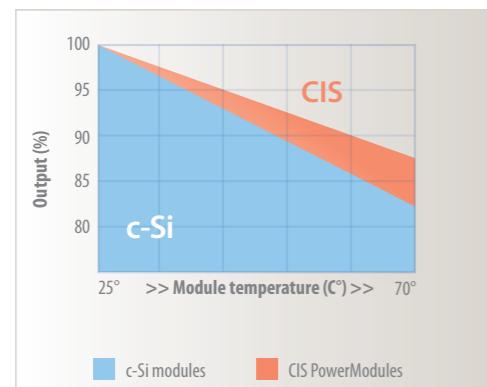


Fig.: Low temperature coefficient means: almost one-third lower energy production losses at high temperatures

e.g. at a module temperature of 70 °C:
CIS PowerModule: -13.9 %
c-Si module (typ.): -20.3 %

Reference: Windhoek, Namibia

The challenge: High daytime and low nighttime temperatures, intense solar radiation

System capacity	69.6 kWp
Annual global irradiance	2,363 kWh/m ²
Average yearly temperature	19.9 °C
Annual precipitation	362 mm



Greater efficiency: „Light Soaking Effect“

Highest yields – and how you reap added benefits.

Now, let's say you're starting your car on a cold winter morning. As long as the motor is still cold it clearly puts out less power. However, the output increases noticeably as soon as the motor has warmed up. The same applies for what is called the „light soaking effect.“

The light soaking effect is the ability of the module to generate several percent more output after about 50 hours of sunshine than it could at the time of its production, which was fixed with flash test values (the electrical characteristics of the PV module under standard test conditions - its birth certificate, so to speak).

The CIS layer applied to the substrate in several work steps is topped by a nanometer-thin

buffer layer. This buffer layer initially forms an energy barrier which hampers the electron flow. Triggered by the photons of the sunlight, the first electrons begin moving and neutralize the initially still existent defective areas in the border of the layers. This makes the energy barrier smaller, facilitates the flow of the next electrons and reduces the series resistance. As a result, the energy flux at the module and the module efficiency are increased.

If the efficiency of a CIS PowerModule increases to a higher value due to the light soaking effect, it will remain stable over the entire life cycle. Output losses occurring over the lifetime of the modules correspond to the natural degradation of less than 0.5% per year.

Confirmed by:

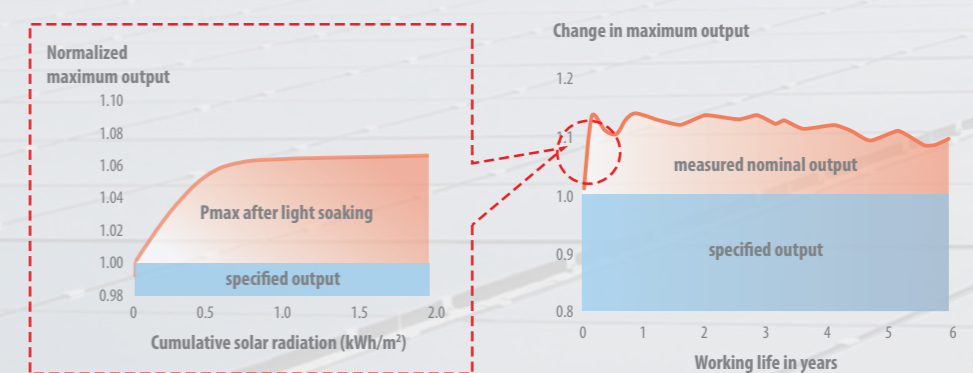


Fig.: Pmax drops by 0.5 %/year (10% in 20 years). On the whole, the nominal power output is maintained. The light soaking effect of the CIS PowerModules results in greater output than that given in our specifications.



Greater security

Reliable quality – reliable partner.

Solar Frontier offers you double security for your solar installation – not only for a product, but also for a company you can depend on.

The modules are manufactured under far more stringent quality assurance requirements than usually customary or required. In addition to standard quality controls, they are subjected to special load and durability tests. This includes a testing station for hardness tests under temperature fluctuations ranging from -40 to +80 °C.

Highest yields – greatest possible security for your investment.

Highest yields at Solar Frontier are also coupled to the greatest possible security for your investment. With Shell and Saudi Aramco, Solar Frontier is backed up by two powerful financial and professional partners who can look back on over two decades of expertise in the energy sector and assure a long-term commitment in the market.

Solar Frontier also has pertinent experience gathered from numerous large-scale projects resulting from collaboration with major EPCs (Engineering, Procurement, Construction) worldwide. Japan, Germany, France, Mexico and Greece are only a few of the countries in which large-scale Solar Frontier installations are producing yields beyond all expectations. End customers in the private sector also profit from our expertise in this area.

An additional safeguard is provided by local contacts: Customers in Europe have found a partner in Solar Frontier with knowledge of local condition and capable of dealing on site with customers' needs. The European headquarters is more than just a sales office; it combines all functions necessary to support customers, including customer service, technical support, marketing and training.

Greater environmental friendliness

Sustainable in every way.

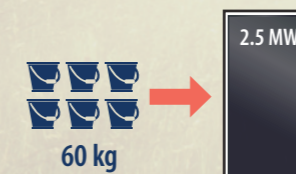
No doubt about it: Generating electricity with renewable solar energy is fundamentally characterized by a high degree of environmental friendliness while conserving resources. And yet the various PV technologies differ considerably among themselves, especially with regard to production methods, raw material requirements and the use of environmentally hazardous substances.

Solar Frontier consistently implements the principal of sustainability throughout its operations – from handling raw materials through manufacturing and on to a virtually waste-free delivery.

- **Eliminating cadmium and lead: no environmentally hazardous materials are processed**
- **One of the few manufacturers to comply with the stringent RoHS guidelines (Restriction of Hazardous Substances)**
- **Extremely low raw material requirement – especially compared to manufacturing silicon modules***
- **One of the shortest energy payback times (EPT) in the market: The energy required to produce one module is recovered in less than one year by the electricity generated by the module.**
- **Replacing cardboard packaging materials with reusable packaging (company's own recovery system)**



* Environmentally safe production through minimal raw material requirement



Solar Frontier needs just barely 60 kg of raw materials to produce CIS PowerModules with a 2.5 MW total output.



7.5 metric tons – over 120 times as much – would be required to produce crystalline silicon modules with the same total output.

Greater aesthetics

Eco-friendly energy has never looked so good.

PV installations were long considered to be reasonable and clever solutions – but definitely not good looking. The CIS PowerModules of Solar Frontier have completely changed that. The black surface and black frame ensure that the modules blend into the architecture and the environs in an aesthetically pleasing way. What's more: in many cases its sleek design even improves the overall appearance of the roof or of the entire building.

The unique composition of our CIS PowerModules is the reason for their typically black appearance, which in some very few cases is slightly cloudy. This is due to what is referred to as the Aurora effect. It is caused by the use of non-toxic materials such as zinc instead of the toxic cadmium. This does not diminish the modules' performance.



Solar Frontier

Highest yields – even under extreme conditions.

World leader in CIS technology.

Solar Frontier is the world's largest and fastest-growing manufacturer of CIS thin-film modules that stand out due to their efficiency, high yield and environmental friendliness. As a 100% subsidiary of Showa Shell Sekiyu K.K., the company is financially strong – which enables it to stand beside its customers as a reliable and long-term partner. Solar Frontier's mission is to develop the most economical and ecological solar energy solution.

Solar Frontier has been a pioneer in the field of solar energy since the 1970s. Today the company possesses unparalleled expertise in research, development and manufacturing. In 2011 Solar Frontier commenced operations of the world's largest manufacturing plant for CIS PowerModules. With a total capacity in the gigawatt range from the total of three factories in Miyazaki, Solar Frontier is the world's leading provider of CIS thin-film technology – and is extremely well prepared for the international demand for solar modules with superior efficiency and high yield capacity. Aside from our headquarters in Tokyo, we have regional subsidiaries in Germany, Saudi Arabia and the United States. We have more than 1,500 employees worldwide.

Reliable local partner: Solar Frontier Europe.

Solar Frontier Europe was founded in 2010 in Munich, Germany, in order to provide optimal care to customers in Europe, Africa and Middle East. However, the company is far more than just a sales office: Solar Frontier unites all services necessary to provide faultless local support to customers. This support includes technical support, project development, customer service and more.

For further information please visit us at:
www.solar-frontier.eu





Solar Frontier – at a glance

Company

- Solar Frontier operates worldwide in the area of solar power solutions
- Our origins are in Japan, our business is global.

Experience

- We have more than 35 years of experience in photovoltaics
- Development of solar technologies in cooperation with the government of Japan and scientists

Research & Development

- We run our own R&D department with more than 200 employees within the Atsugi Research Center (Japan)
- Our CIS modules already set numerous world records in module efficiency

CIS technology

- Market leader in CIS technology (copper (C), indium (I) and selenium (S))
- World's largest manufacturer in the gigawatt range

Financial strength

- Financially strong shareholders Shell and Saudi Aramco
- Comprehensive track record of major debt-financed projects

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