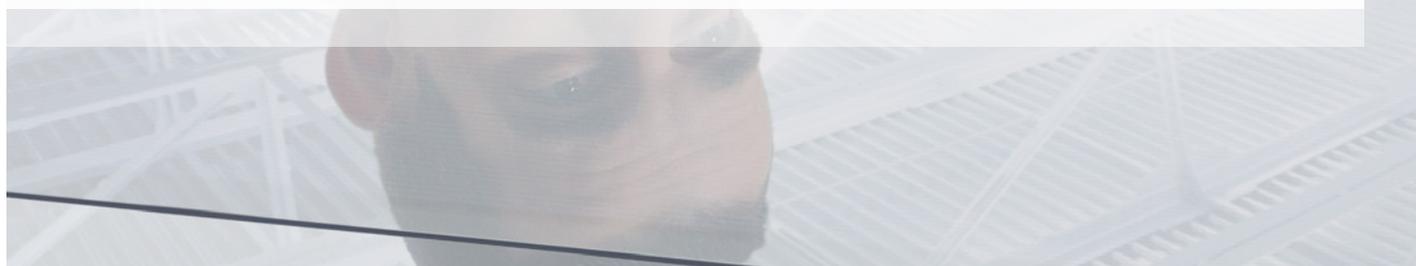


CIGS PRODUCTION SOLUTIONS



CIGS Turnkey Production Line

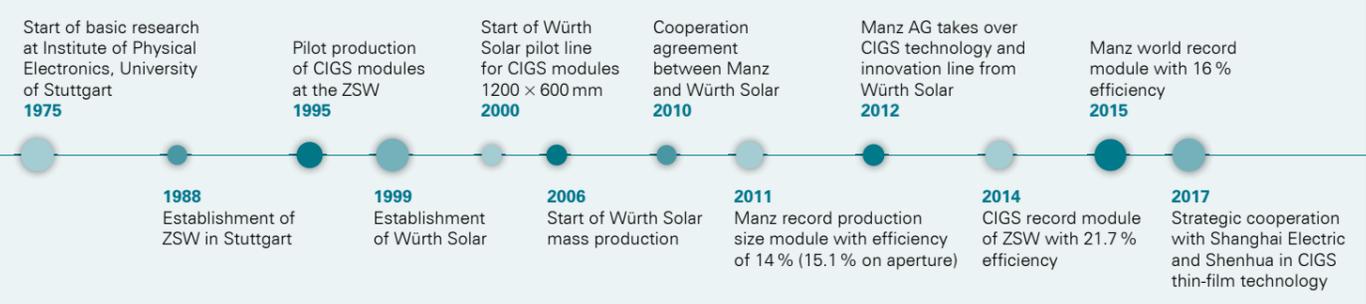
The perfect model for creating value locally





CIGS—THE PHOTOVOLTAIC SOLUTION FOR TODAY AND TOMORROW

CIGS HISTORY OF MANZ



The CIGS Story

AS ENERGY REQUIREMENTS INCREASE WORLDWIDE, THE PERCENTAGE OF RENEWABLE ENERGY SOURCES IN THE OVERALL ENERGY MIX IS ALSO GROWING. PHOTOVOLTAICS — DIRECT CONVERSION OF LIGHT ENERGY TO ELECTRICAL ENERGY — PLAYS A CRUCIAL ROLE IN THIS DEVELOPMENT.

CIGS development already has more than 40 years of history in southwest Germany. After the first pilot production of a CIGS module in 1975 at the Institute for Physical Electronics (IPE) at the University of Stuttgart, the founding of ZSW in 1988, and the start of mass production in 2006, Manz has contributed to the breakthrough of the CIGS technology from 2010 till today.

As a **pioneer in designing and building equipment for the solar industry, Manz has 30 years of experience** in taking photovoltaics from the laboratory to the factory floor. Manz' solutions have helped solar companies offer their products at a fraction of their original cost and bring them to market faster and faster.

In the beginning of 2017, Manz AG and affiliated subsidiaries of Shenhua Group, Shanghai Electric, and Beijing Future Science Park Development Group founded a unique R&D Joint Venture that will become the **world-leading research company dedicated to the CIGS thin-film technology**. This R&D Joint Venture will leverage the potential of CIGS for further efficiency increase and reduction of manufacturing costs. With the objective to further accelerate the R&D process, an R&D line will be installed in Beijing in addition to the existing one of Manz in Schwaebisch Hall, Germany.



MANZ

Manz AG is a globally active high-tech equipment manufacturer and—with an experience of 30 years—pioneer in mechanical engineering for the solar industry. With its CIGSfab, Manz is the world's only provider of a fully integrated, turnkey production line for manufacturing CIGS thin-film solar modules.

SHENHUA

The Shenhua Group Corporation Ltd. is the largest and most modern coal enterprise in China and the world's largest operator of coal mines. Shenhua is one of the largest energy producers in China. The conversion of the energy generation portfolio to renewable energies has already been initiated with massive investments in wind energy and has now been continued with the investment in solar energy.

SHANGHAI ELECTRIC

Shanghai Electric is anchor investor of Manz AG and one of the largest and most comprehensive equipment manufacturing conglomerates in China, possessing four main businesses with regard to high efficiency & clean energy, new energy, industrial equipment, and modern services. The core business is still the construction of fossil power plants for coal and gas.



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WHAT IS CIGS?

CIGS stands for the power generating semiconductor material consisting of **copper, indium, gallium, and diselenide**. This semiconductor is evaporated as a very thin layer (“thin-film”) on a glass panel during an innovative co-evaporation process. **Among thin-film technologies, CIGS offers the best potential when it comes to low production costs and high efficiency.**

ALWAYS THE LATEST TECHNOLOGY

The ZSW (Centre for Solar Energy and Hydrogen Research Baden-Wuerttemberg) is one of the leading European research institutes in the field of photovoltaics. The materials researchers at ZSW are **specialized in CIGS thin-film technology** and the development of new material systems. Today, CIGS technology is the thin-film technology with the **highest levels of cell efficiency.**

Manz has **exclusive access to the ZSW's CIGS thin-film technology**, which is continuously developed and transferred to the mass production processes.

Technological upgrades for investors in the CIGS technology are a firm component of Manz' business model.

CIGS Technology— Securing lowest solar energy production costs

CIGS IS THE SOLAR TECHNOLOGY WHICH OFFERS LOWEST PRODUCTION COSTS ALREADY TODAY AND BEARS THE HIGHEST POTENTIAL FOR BOTH FURTHER INCREASES IN EFFICIENCY AND REDUCTIONS IN COST. AND CIGS OFFERS ADDITIONAL UNBEATABLE BENEFITS COMPARED TO THE CRYSTALLINE TECHNOLOGY.

Efficiency

Already today, the efficiency of the Champion Module is roughly at the level of multi-crystalline cells. The enormous potential is demonstrated by the highly efficient cells (in small, laboratory format) of the ZSW. The ZSW's technology is constantly being transferred to the mass production processes of the CIGSfab.

Costs of energy generation

The cost advantage of CIGS technology increases by considering the actually relevant costs of power generation, the costs per kilowatt hour. If a CIGS module and a crystalline silicon module with the same nominal power are installed next to each other, the CIGS module generates 10 % to 15 % more power during the year. This is because of the physical properties of the CIGS modules: In weak light, so in the morning and evening hours as well as in the case of cloudiness or smog, they generate more energy than silicon modules. Another great advantage during the summer months and especially in areas with higher temperatures is the better temperature coefficient. This feature of the CIGS semiconductor ensures that a CIGS module generates more power at high temperatures than a silicon module.

Costs per watt

Considering the costs per watt (the actual manufacturing costs of the solar modules), those of the CIGS technology are already today significantly lower than those of the crystalline technology. As a result of the planned scaling of the production capacities, they can be dramatically reduced again.

Highest level of local value creation

CIGS panels are manufactured on a fully integrated production line. The process starts with a basic glass substrate. To manufacture a CIGS panel, only a few different conductive layers are deposited onto the substrate, which are then connected electrically. This means that compared to crystalline solar cell production, the use of cost-intensive materials (like silicon) is kept to an extreme minimum. The production of a panel is far less complex and the largest portion of the value chain—beginning with the production of the glass panels—takes place within the country.

Sustainable production

One of the benefits of CIGS is the low amount of material required. While present-day crystalline cells are around 200 μm thick, the CIGS absorber is less than 2 μm thick. This saves material during production and is sustainable and environmentally friendly.

Expanded fields of application

Due to their uniform black surface, CIGS modules give a better aesthetic impression. This leads to an excellent suitability for use in building-integrated photovoltaics. Both roof-integrated CIGS modules as well as façade modules represent a visually appealing and, above all, energetically viable alternative to conventional building materials.



CIGSfab—Unrivaled profitability

FOSSILE ENERGY RESOURCES ARE LIMITED—LOCALLY PRODUCED RENEWABLES ARE THE FUTURE. CHOOSING THE CIGSfab MEANS SELECTING A MATURE BUSINESS MODEL FOR YOUR INVESTMENT.

Under the brand name CIGSfab, Manz offers fully integrated, turnkey production lines. As of today, the CIGSfab is the only integrated and fully-productive turn-key production line for CIGS modules that generates profit.

But there are even more reasons to invest in one of these lines:

Lowest cost of generating power from solar technology

When it comes to producing energy from photovoltaics, CIGS is the technology that promises the highest achievable margins. This mature technology is ready for use—now.

The CIGSfab is scalable

The CIGSfab is available with an output from 65 MW up to Gigawatt level. A 65 MW CIGSfab can also be expanded at a later time when customers need to increase their production capacity.

Possibility to upgrade

Each CIGSfab can be upgraded to the current state of technology developed at the ZSW and tested at the CIGS innovation line any time. This guarantees that a plant constructed today can also be operated profitably in the future as well.

Documented and reliable technology roadmap

The CIGS innovation line can be used to test and optimize new innovative processes, alternative materials, and new panel designs in mass-production conditions. This significantly accelerates the development of CIGS technology and minimizes the risk of delays when ramping up production.

Module reliability

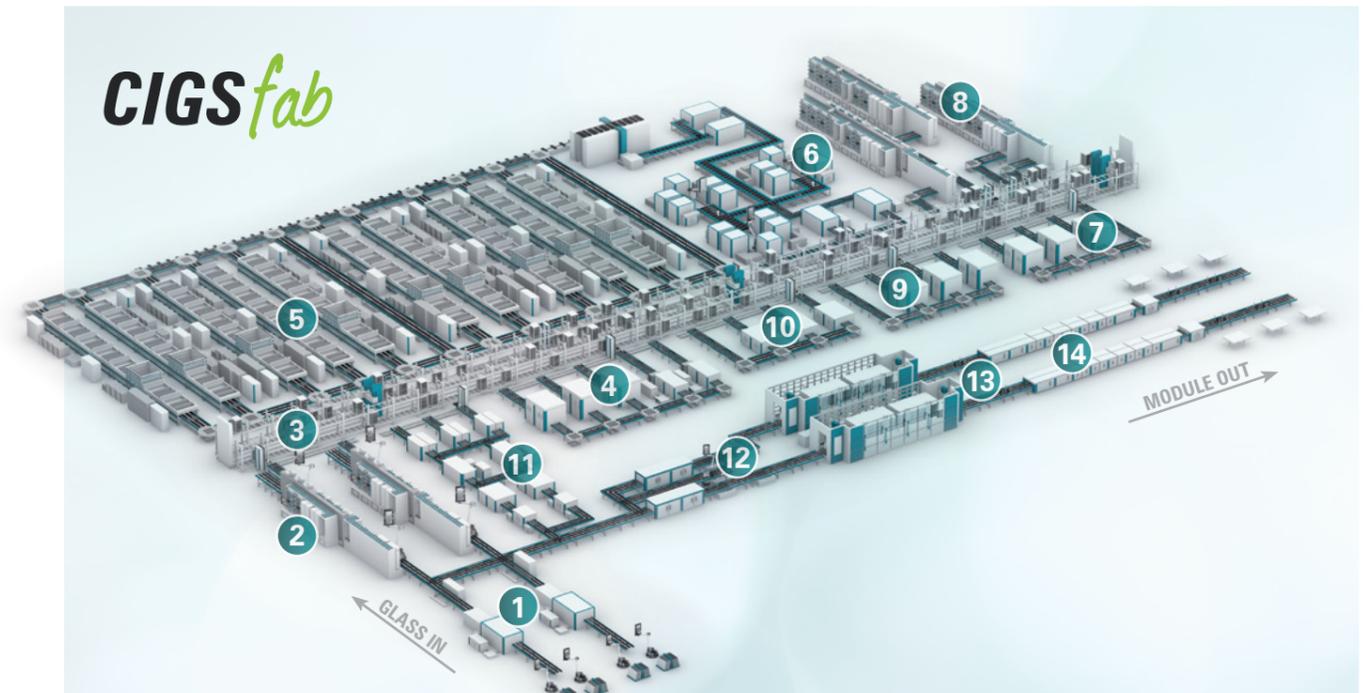
A large number of Manz CIGS modules have been installed worldwide. References from all parts of the world and from all climate zones verify the reliability of the CIGS modules that are produced in the CIGSfab.

A highly secure investment

Each CIGSfab offers outstanding investment security due to a maximum efficiency potential and a reliable technology and cost roadmap. Technological upgrades for our customers are a firm component of our business model.

Financing

Leading financial institutions around the world have already financed solar power plants that use Manz technology.

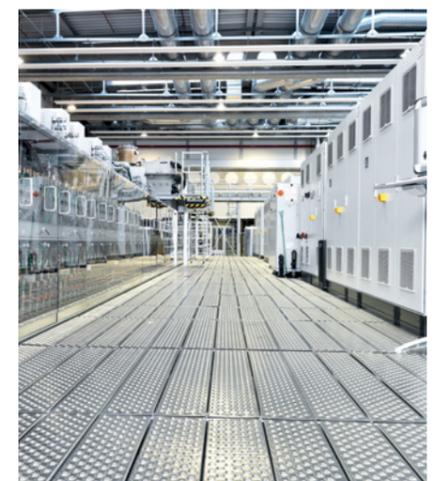


1 Cleaning	6 CBD-CdS + ZnO Coating	11 Laser Drilling + Contacting
2 Mo Coating	7 P2 Scribing	12 Module Marriage + Lamination
3 Automation	8 ZnO:Al Coating	13 Junction Box Assembly
4 P1 Scribing	9 P3 Scribing	14 Light Soak + Sun Simulator
5 CIGS Coating	10 Laser Edge Ablation	

WHAT IS THE CIGSfab?

The CIGSfab is a fully integrated, turnkey production line for CIGS thin-film modules. In the CIGSfab, a solar module is manufactured starting from a normal glass panel in a fully integrated and automated production process.

The production process for CIGS modules is significantly shorter and less complex, and the production costs are much lower than for crystalline solar cells. This has also a positive effect on the payback time of the energy used for the production of the module: while this is around two years for crystalline solar cells, it has been reduced to under nine months for CIGS modules.



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