

# POWER GENERATION TODAY

Produced by:

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#### Printed by:

Typo Colour Printing  
Tel: (011) 402-3468/9

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## Whipping up a Solar Factory

To be able to compete, photovoltaics manufacturers have to develop large production capacities fast and produce efficiently. Upstream suppliers help them to expand by offering complete, turnkey lines that they install and run in a short period of time while guaranteeing their output; and the industry is only too pleased to accept these turnkey installations.



**C**an you purchase a plant where you only have to roll the gate open and start producing right away? This is the promise made by so-called turnkey plants, ready-built manufacturing sites for silicon wafers, cells and modules that many overseas PV (photovoltaics) suppliers offer these days.

**Solar producers benefit from turnkey solutions of this kind because it allows them to ramp up large manufacturing capacity fast**

Originally these machinery and plant builders only offered equipment for one specific manufacturing process, manufacturing lines were therefore always the product of numerous specialised outfitters. Today, they supply the complete lines as single-source suppliers – commissioned and with guaranteed output parameters such as yield,

throughput, availability and efficiency.

Solar producers benefit from turnkey solutions of this kind because it allows them to ramp up large manufacturing capacity fast – bringing costs down rapidly. However, building a solar factory is a complex business.

A plant consists of lots of equipment that differs according to product and production process," explains Eddy Blokken, the former Head of Technology and Standards at the Semi-Conductor Association Semi Europe and an expert in solar manufacturing technology. For crystalline silicon technologies the four steps of the value chain – silicon, wafer, cell and module production – are generally carried out in separate factory buildings. Each one of these products is based on many individual process steps: silicon is prepared and crystallised into blocks; the wafers cut from this are processed into solar cells by another special

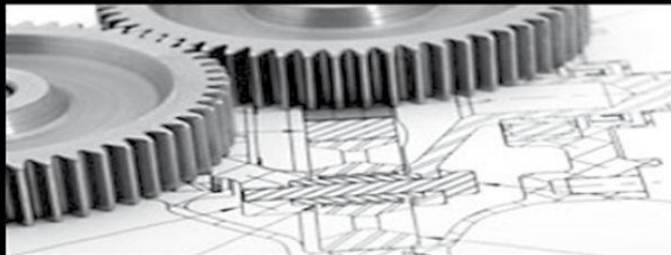


Building a turnkey factory: employees of Centrotherm install a so-called CVD-reactor for silicon production. (Source: Centrotherm)

treatment, which are in turn electrically connected, laminated and framed. The production of thin-film modules, on the contrary, is a condensed process occurring in one building.

**A future producer needs a minimum of five people with at least five years of PV experience to fill the core positions for a turnkey factory**

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### One-stop shopping for all processes

Customers' needs also differ. "Our clients are either newcomers in the business with little know-how under their belt or experienced "solar players" with a very clear idea about their new manufacturing site," says Chris Buckland of the Berlin-based factory planner *ib vogt*. Well-established producers who wish to expand their capacities rely on the machinery proven to be the best for their process. "In such cases we prefer to focus on turning their wishes into reality," adds Chris.

In contrast, newcomers, such as financial investors, need assistance in scouting the right location, infrastructure, planning and construction of the building as well as the installation of the line. Such newcomers prefer solar factories that have already been erected exactly the same way elsewhere and are tried and tested.

### All by themselves

Chris adds, "Unfortunately, these customers believe that turnkey plants run all by themselves. To build the factory halls and fill them with equipment is not the problem. This can be done in twelve months. But the lead-time required until the first marketable products are available is very lengthy with these new producers, "taking six months or more". In his experience, a future producer needs a minimum of five people with at least five years of PV experience to fill the core positions for a turnkey factory. Otherwise only rejects will be produced for a long time – probably for too long.

The pioneers in turnkey factories are Centrotherm and Gebrüder Schmid from southern Germany. The first lines for manufacturing crystalline cells were built after the turn of the century. But as the number of new market entrants rose, the demand for quick-build greenfield production sites increased with ever-widening product portfolios.

### SMEs now building large giga-factories

This trend towards integrating as many technologies and process steps as possible continues unabatedly. Some companies concentrate on the development of new products and processes buying in the necessary expertise and machinery. This is the approach taken by Centrotherm, a "heavy weight" in this industry. With a view to pushing vertical integration across the entire solar value chain, the Swabians have taken over a number of specialised suppliers, Michael Glatt Maschinenbau, a producer of pressure vessels for silicon reactors, Solmic, the silicon production expert and GP Solar, the module line engineering firm.

Other enterprises, on the contrary, enter into strategic cooperations in order to be able to offer turnkey plants. A real professional at installing such networks is the Schmid Group. It leads a consortium that has now been joined by many specialised suppliers. The portfolios of these companies are complementary and jointly they can install turnkey

wafer, cell and module lines of up to one gigawatt (GW) capacity.

### Given a boost

The turnkey movement was really given a boost when thin-film mass production started. Companies such as Applied Materials in the USA, Oerlikon in Switzerland or Ulvac in Japan “pricked up” their ears. Leveraging their expertise in plant engineering for the semi-conductor and flat-panel screen industry, they’ve started focusing on solar energy too – and soon became established suppliers of turnkey PV lines.

Having observed this trend, Arnulf Jäger-Waldau of the Institute for Environment and Sustainability at the Joint Research Centre of the EU (JRC) in Italy says, “In 2007, firms announced that they would soon offer a turnkey line. By 2009, 20 firms already offered turnkey solutions.” Without this development, photovoltaics would probably not have experienced such a rapid growth. According to the European Photovoltaic Industry Association (EPIA) global manufacturing capacities for crystalline and thin-film modules amounted to 15 GW in 2009 from a low of 250 MW in 2000.

### Automation from the automotive industry

More and more firms are turning to photovoltaics to cash in on the PV boom. The OEMs of the crisis-stricken automobile industry especially are now turning their robots “towards the sun” when seeking new buyers of their assembly line expertise. As Markus Meier, the marketing manager of Kuky Systems in Augsburg, puts it, “Being OEMs for the automotive industry, the sector boasting the highest degree of industrialisation, we can also make solar factories leaner, faster and more flexible.” Kuka delivers module lines with up to 100% automation.

Also gaining a firm foothold in the PV sector is the Southern Franconian robot producer Reis Robotics. Early 2000 still saw them deliver primarily infrastructure for automotive production – today they are already generating half their sales with solar



Turnkey module line robots assume a crucial function – they ensure faster production. (Reis Robotics)

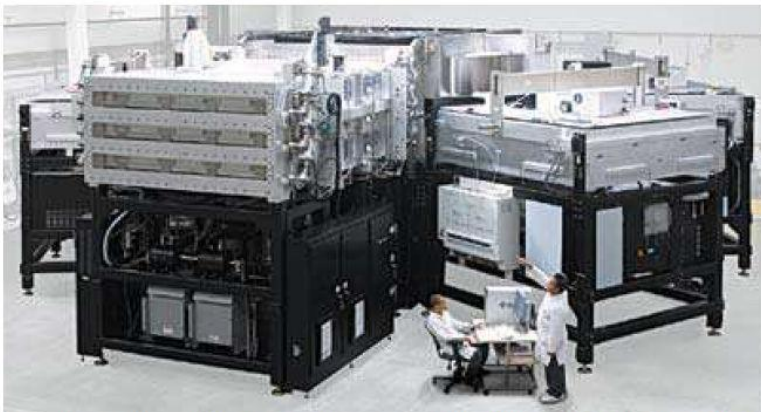
### How a solar module comes into being

Many production steps are required to make modules out of silicon. Usually, silicon is produced by way of chemical distillation in special reactors. Subsequently, it is molten in crucibles, crystallised to form ingots, which are then cut by dicing saws into the so-called wafers. These wafers are first cleaned in chemical baths, then etched to produce a surface suitable for collecting light. After this texturing, the electrical properties of the silicon are set.

To this end, a diffusion furnace is used to make phosphor atoms migrate into the crystal with the aim of achieving a surplus of electrons at the surface – the decisive prerequisite for producing electrical energy. Then anti-reflective and deadening layers are applied to the “semi-finished” cells. These ensure that more light enters the cells and can be absorbed.

The coating process of choice is chemical vapour deposition (CVD). In this process, silicon nitride or titanium oxide is deposited on the surface. In the module line, the individual cells are then contacted into strings by tabber-stringers and brazed. Subsequently, a laminator thermally welds this composite cell under vacuum between two glass sheets and several plastic films making it weather-proof. Finally, the module is fitted in a frame with a junction box and is ready for mounting on roofs or in solar power plants.

## POWER GENERATION



New dimensions: thin-film module production equipment. Here the Sunfab by Applied Materials, has a big footprint – posing a big challenge to factory planners. (Source: Applied Materials)

Thin-film manufacturing is a continuous process. Contacts and semi-conducting materials – layers that are many times thinner than silicon – are applied directly to a substrate (as a rule glass). There are different ways to do this: usually physical and chemical vapour deposition is used. In this process, the semi-conductors are sputtered or vapour-deposited in sheer layers at high temperatures in special reactors. In the sputtering process, atoms are extracted from a solid body by bombarding it with high-energy ions. These condense and are deposited on the substrate. After processing, the cells are provided with a protective glass sheet.

equipment and turnkey module lines according to General Manager, Eberhard Kroth. Having supplied (car) glass lines for many years, the enterprise boasts impressive manufacturing technology expertise. The plants delivered by Reis in 2007 produced modules with an output of 850 Megawatts (MW); only a year later this figure had gone up to 1.6 GW.

### External expertise

While turnkey module lines are numerous, there are fewer and fewer turnkey solutions on offer the closer you get to the beginning of the value chain. The reason being the complex production of the upstream products and silicon, in particular. The British ingot and wafer producer PV Crystalox has erected a silicon plant completely with its own resources since there was no external expertise available for buying in. Plant Manager Hanno Wilhelm knows why: “There is a great deal of “cloak and dagger” in this segment.” Who would voluntarily provide their competitors with a plan of the complex production of these valuable semi-conductors?

2007 finally saw PV Crystalox start building their facility, which has subsequently gone into operation. But now there are even “off-the-shelf” factories for elaborate silicon production. Centrotherm launched its fully integrated factory in spring 2009: the complete

production from silicon to finished modules is available for just under EUR 1 billion.

### Rapid ramp-up

But what are the benefits of these off-the-shelf factories? "Clearly the rapid ramp-up of capacity," says Jäger-Waldau.

This view is also shared by the well-established producers – which is why more and more of them expand with the help of turnkey facilities these days. But they use their own factories as a blueprint, mirroring them on the adjacent greenfield site, so to speak. Most equipment suppliers grant output guarantees that provide for some breathing space in the initial stages. Alternatively, they can build a factory based on their own research and development activities.

A case in point being the leading thin-film provider, First Solar. However the drawbacks of this strategy also become evident: it took the Americans eight years and \$ 140 million to achieve the ramp-up phase – no new entrant could afford to wait that long these days.

### The downside of turnkey

The downside of turnkey installations is the restricted possibility of creating USPs so as to stand out from competitors who are probably already running the same factory at another location. "Then you can only stand out with economies of scale, ie, a faster expansion of mass production," says Jäger-Waldau. When installing the first line, planning for the second one must already be underway. However, growth presupposes that the factory operator will change his business model speedily and accumulate in-house expertise, which is anything but easy considering the enormous development pace in PV.

In addition, new equipment cannot just be incorporated into an existing line without any refitting because there are no uniform standards governing this field as yet. The issue of poor compatibility has at least been identified and is now to be addressed. The PV Group at Semiconductor Equipment and Materials International (Semi) Europe has evaluated measures designed to optimise manufacturing processes. "This means the best available technology could be easily integrated into existing lines," says manufacturing expert Blokken and adds that Semi already maintains close links with the industry. It will soon be clear whether and what standards will be accepted by manufacturers.

### Dead-end street

However, turnkey facilities can also become a dead-end street for machinery and plant builders. Competition is growing and manufacturing technology innovations are developing fast so that suppliers can easily lose track of the latest trends in the race for the most efficient and biggest production line.



Checking the core machine: in a horizontal furnace wafers are processed further into cells. A Centrotherm technician checks its ready status. (Source: Centrotherm)



Moving in: Oerlikon employees take the first thin-film systems into the factory of the Berlin manufacturer Inventux. (Source: Inventux)

Small and medium-sized companies are better off today specialising in one type of machine rather than trying to offer turnkey solutions, says Jäger-Waldau. "Modules are commodities and this mass product will in future be manufactured by high-capital global players located in Asia rather than in Europe."

**While turnkey module lines are numerous, there are fewer and fewer turnkey solutions on offer the closer you get to the beginning of the value chain**

Enterprises such as Samsung, LG or Hyundai have already "staked their claim" and will most probably be tomorrow's solar tycoons. These would admittedly also implement turnkey solutions but in magnitudes that are out of the scope of SMEs. This is why specialisation is most probably the most sustainable strategy for SMEs. They should concentrate on innovative equipment for the long PV supply chain.

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