PhotoVoltaic
EUROPEAN TECHNOLOGY & INNOVATION PLATFORM

PV MANUFACTURING IN EUROPE

CONFERENCE REPORT
18-19 MAY 2017

www.etip-pv.eu

Author

Greg Arrowsmith

With thanks

to the following for confirming the quotes attributed to them and/or providing supplementary material:

Eric Ast
Andrea Canino
Xavier Daval
Martin Fischer
Martin Hermle
Luc de Marliave
Gaëtan Masson
Christoph Mayr
Massimo Mazzer
Milan Nitzschke
Mark Osborne
Emiliano Perezagua
Stefan Reber
Fabrice Stassin
Gerhard Strobl
Marko Topič
Wijnand van Hooff
Andreas Wade
James Watson
Trond Inge Westgaard
Peter Wohlfart

In memoriam Emiliano Perezagua
(1957-2017)

Layout and Printing

Secretariat of the
European Technology and Innovation Platform for Photovoltaics
Tel: +49-89-720 12 722
Fax: +49-89-720 12 791
info@etip-pv.eu

Disclaimer

"The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727272"

Table of Contents

Introduction

ETIP-PV, the European Technology and Innovation Platform on Photovoltaics, held a conference, PV manufacturing in Europe on 19 May 2017, preceded on 18 May by an invitation-only meeting for associations and public officials.

This report is compiled from statements made at both events. It captures the key themes that were raised and, where possible, feels its way towards conclusions.

It is the sixth initiative of ETIP-PV in this topic, following:

- Conference 2014: New dawn for large-scale PV manufacturing in Europe: reality or pipe dream?
- Position paper 2015 (see p35): Future of the Photovoltaic Manufacturing Industry in Europe
- Report 2016: The European PV Manufacturing Industry: Analysis and Policy Guidance for 2020 and Beyond
- Conference 2017: PV Manufacturing in Europe
- Open letter and petition effort 2017: Urgent Call for Action to Ensure a Sustainable Future for European PV Manufacturing

Key messages

To become competitive or regain competitiveness, there are things that European manufacturers can do, and things that policy-makers can do.

For manufacturers

European manufacturers need to focus on producing hardware that is of the highest quality and to find a way to persuade customers to pay more for such products. One way is for the producers of modules to own and operate projects that use them, i.e. pursue a strategy of deep vertical integration.

They also need to bring to market new products that anticipate their customers' needs. Higher efficiency is one well-known need, longer lifetime is another; but there are less explored avenues: modules that are particularly easy to install, for example, or PV on cars. Building-integrated PV requires close engagement with the end customer This and the bulkiness of building elements makes European manufacturing supply chains attractive.

Established PV manufacturers in Europe have often found it helpful to be business units in a company with a broader focus.

For policy-makers

Policy-makers need to provide low-cost finance to investors in manufacturing. The support available in China is far greater than in Europe.

Fair trade has priority over free trade. It would be ideal if countries trading PV could agree how they would each support their domestic manufacturers, and stick to the agreement. If this can't be achieved, different ways to level the playing field will be needed.

Measures to stimulate demand for PV in Europe will, on their own, not guarantee that the demand will be met with Europe-made products. Any manufacturing plant in Europe will need exports as part of its business plan.

Governments can help the competitive position of Europe-based manufacturers by funding R&D, particularly collaborative projects between research institutes and companies.

1 The health of the industry – snapshots from different countries

Upstream

Feedstock

James Watson (CEO, Solar Power Europe) said a European company producing in Europe, Wacker, was the leading seller of silicon in 2016. That could be temporary, cautioned Arnulf Jäger-Waldau (European Commission Joint Research Centre): Chinese rival GCL had in 2016 closed some production for upgrades.

Norway is home to other silicon producers. Trond Inge Westgaard of the Research Council of Norway said his country's PV sector had rebounded, with significant job growth in recent years upstream. Elkem Solar produces 6 000 tonnes/year of solar-grade silicon. Norsun produces 350 MW/year of mono-Si wafers. Both are planning increases. Norwegian Crystals produces mono-Si wafers, too, at a smaller capacity than Norsun. The Quartz Corporation supplies materials for crucibles to the Norwegian and Chinese markets.

Nexwafe will open a pilot (5 MW) production facility for "epiwafers" in 2018 in Freiburg, Germany, followed by a 250 MW commercial facility.

Equipment manufacturing

Growing Chinese competence…

Jäger-Waldau presented a slide that was referred to several times during the two days. It showed how cheap it is today to install large production capacities in China, with a 10x reduction in cost in five years (Table 1 – 2011-2016):

Year	Capacity [MW]	Country	CAPEX [mil. USD]	CAPEX/W [USD]
2011	1 000	USA	680	0.68
	1 000	China	510	0.51
2014	1 000	USA	430	0.43
2015	1 000	China	190	0.19
2016	1 000	China	60 hardware only	0.06
2017	600	China	97 N-HJ (hardware + tf infrastructure)	0.162

Table 1 While in the early part of the decade much of the equipment may be assumed to come from Europe, Jäger-Waldau explained, the 2016 1000 MW line costing 60 M USD would use exclusively Chinese equipment, producing standard cells and modules. The 2017 600 MW line uses state of the art technology: "N-HJ" refers to silicon heterojunction solar cells on n-type wafers. This equipment does not necessarily come from China.

Reacting to the slide, Emiliano Perezagua (consultant) thought European companies remained dominant in the supply of PV manufacturing equipment, except for diffusion furnaces. They had reduced their prices, with 25 M EUR now buying a 100 MW/year line, but were also selling more. Their price is not far off the 97 M USD for a 600 MW/year line mentioned in the slide. But Jäger-Waldau and Xavier Daval (KiloWattsol) disagreed: "Even in 2011, the backlines of a number of companies I saw on my tour of Chinese facilities had other equipment (non-European made). It looked very much the same, but wasn't" (Jäger-Waldau).

…is met with European confidence

Sales for German-made PV manufacturing equipment were 20% higher in 2016 than 2015, reported VDMA in May, and an optimistic mood was detectable in the speakers from this sub-sector.

Peter Wohlfart of Singulus said his company was not alone in receiving a large order for thin-film equipment. Benjamin Strahm of Meyer Burger thought good times had arrived, but didn't feel they were necessarily here to stay.

Equipment manufacturers and materials producers based in the Netherlands survived the downturn rather well, said Wijnand van Hooff of TKI Urban Energy. There is a "large" number[1] of them and they are still playing a major role. Several large players in engineering and construction are active in PV.

[1] Slide 2 of his presentation

1 THE HEALTH OF THE INDUSTRY – SNAPSHOTS FROM DIFFERENT COUNTRIES

Mid-stream: cell and module production

Table 2, prepared by Jäger-Waldau shows the status of solar cell and thin film manufacturing in the EU and Turkey.

Company name	Country of production	Cell capacity /MW	Module capacity /MW	Ownership
Solarworld	DE, USA	1070 (320)	950 (550 in US)	29% Qatar Solar 20.85% Dr. Asbeck 50.15% free float
China Sunergy	CN, TR	800 (300)	900 (300 in TR)	OTC traded n/a
Aleo Solar	DE	200	200	Sino-American Silicon Products (TW)
AVANCIS (tf)	DE	120	120	China National Building Materials Group Corporation (CN)
Solland	NL	135	135	Trina Solar (CN)
3SUN	IT tf & (HJ)	160 (80)	160 (80)	ENEL Green Power (IT)
Solibro	DE	120	120	Hanergy (CN)
Calyxo (tf)	DE	85	85	Solar Fields (USA)
Photowatt	FR	75	75	EDF Group (FR)
Baltic Solar Energy	LT	70	70	private
Solsonica	IT	40	144	GALA Group (PTC with 14.46 free float)
Solarion (tf)	DE	20	20	OC3 AG, a subsidiary of Turkish NUH Group (TR)

Tables 2 Status as at May 2017. Jäger-Waldau has also collected data for module manufacturers who use third-party cells (not displayed on this table). There the situation "looks a bit more promising, but not much." "The largest module manufacturer in Europe after Solarworld is an OEM manufacturer, which is owned by an American company producing for Chinese companies in Poland." [Ed. note, Jabil, with 700 MW/year capacity, according to its website[2]]

[2] https://www.jabil.com/solutions/by-industry/enterprise/energy-industrial/solar.html - retrieved on 30 August 2017

These are lean times for cell and module manufacturers, said Jäger-Waldau: "PV cell and thin film capacity is still larger than demand. In this sector, still almost no-one is earning money. It is not sustainable. Selling prices have to meet costs. The industry mustn't go bust." Luc de Marliave of Total backed up him, "We say solar should be competitive, but that means that all the segments should be profitable, which is not the case today. I see losses everywhere in the upstream part. Insolvencies…bankruptcies… no-one's making money. This is not sustainable."[2] Solarworld, two weeks before the conference, announced that it was insolvent. Since the conference, newly founded SolarWorld Industries GmbH has taken over key manufacturing and business assets of insolvent SolarWorld AG in Germany. The new company restarted cell and module production, while for crystallisation and wafering it's looking for investors. "The R&D department is to be transferred to a non-for-profit entity in cooperation with industrial partners to ensure and increase high-level R&D for the EU industry," Nitzschke has added in a statement.

The mood in Lithuania was grave, with Juras Ulbikas of Lithuanian PV Technology Cluster describing his country's industry (80 MW/year cells; 190 MW/year modules) as being "in trouble" and "running at maximum 50%" currently. This is enough for it to "just survive". He said Solitek, the only cell producer, which had been an early adopter of PERC technology for its multicrystalline cells, had stopped production. Manufacturing such cells stopped being "cost competitive in 2016 when the price of cells dropped."

ENEL Green Power's Andrea Canino agreed prices had dropped "dramatically" during the second half of 2016, in "all parts of the value chain" (represented as components of a stack in Figure 1 below):

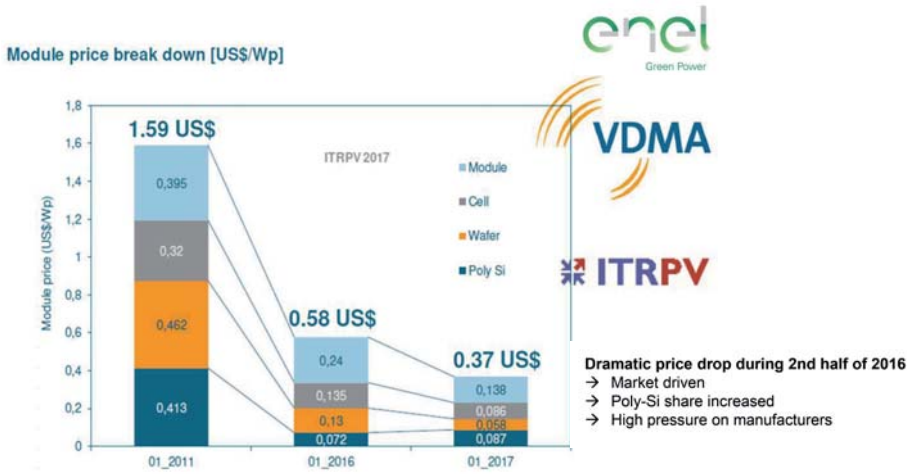


Figure 1 Breakdown of module price according to EGP, VDMA and ITRPV

[3]*See also Solarworld's annual group report 2016: "From mid-year, the international market for solar power products was hit by an unexpectedly sharp drop in prices, triggered by a collapse of the Chinese domestic market. This resulted in a further increase of already existing overcapacities in China."*

1 THE HEALTH OF THE INDUSTRY – SNAPSHOTS FROM DIFFERENT COUNTRIES

But other data appears to show that prices have moved differently. Module manufacturing has seen a steep decline, but cell manufacturing saw a slight price rise over the last two quarters of 2016, according to Gaëtan Masson of Becquerel Institute (Figure 2).

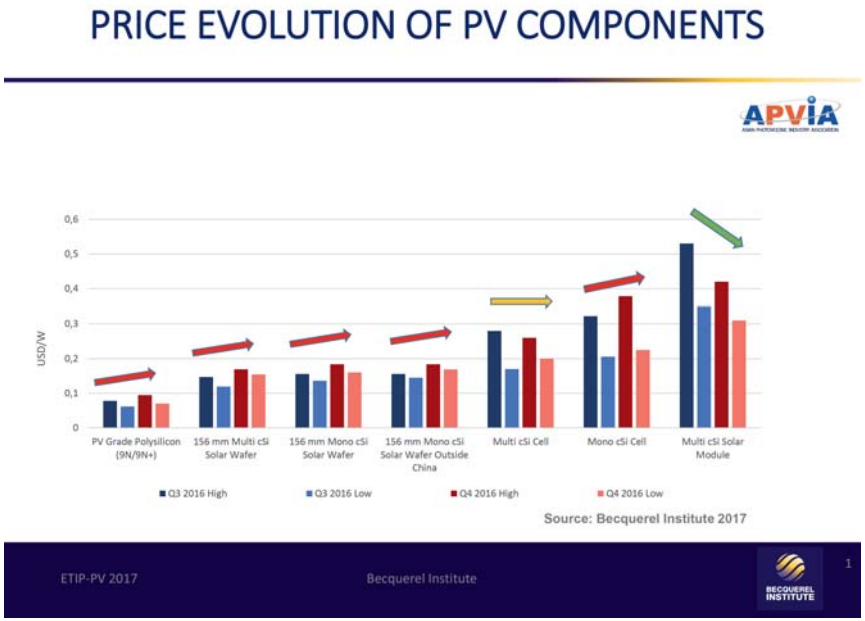


Figure 2 Masson said the same trends had been observed in the first quarter of 2017. In CPV, 30% of the value is in the cell, said Gerhard Strobl of AZUR Space.

Several start-up companies plan to build new manufacturing capacity in cells or modules in the Netherlands, said Wijnand van Hooff of TKI Urban Energy.

An important new venture in cell manufacturing is starting in Italy. ENEL Green Power is re-purposing its 3Sun fab. The new technology choice for the fab, heterojunction technology, is discussed in the next chapter. It is, in EGP's words, the "biggest Italian PV fab and one of the biggest in Europe" and will have a capacity of 240 MW_p/year when work is completed in 2020. It employs and will continue to employ 300 people and, indirectly via its subcontractors, a further 600.

Downstream

Inverters

The Netherlands has "some small companies" in the BoS component producer space. Watson described SMA has having leadership in inverters and that its leadership position could be maintained. José Donoso of UNEF agreed: Europe leads in "inverters, EPC, O&M and design, and in many aspects of R&D". But Emiliano Perezagua (Consultores de Energía Fotovoltaica SL) felt uneasy. Referring to possible installations in China of 18 GW in Q2 of 2017, he feared the sheer volume of the Chinese market will propel Chinese inverter manufacturing to an unassailable lead, helped by the fact that those companies can be loss-making in China, but not in Europe.

Building-integrated PV ('BIPV')

A "large number of new players are active" in this area in The Netherlands (van Hooff).

2 Analysis of technology trends

This section lays out the speakers' views on technology trends. Developing and commercialising new technology was recognised as a necessary component in any strategy for Europe to maintain or regain competitiveness in PV manufacturing.

Taking a leap in novel wafers

Stefan Reber of Nexwafe, which manufactures monocrystalline silicon wafers by epitaxy, thinks that by 2018, the market share of monocrystalline wafers will exceed that of multicrystalline silicon.

The "helicopter view", said Reber of his company's epiwafers, is that by avoiding five resource-intensive steps necessary in the conventional production process, his cells "must be cheaper." This is crucial to his company's competitiveness. He is "not kept awake at night" by LONGI – a Chinese producer of wafers using conventional methods that is expanding rapidly. Rather, competition comes from the US – Crystal Solar – which holds the record in epiwafer efficiency (Nexwafe has the record in current density).

Nexwafe has two routes for reducing the amount of silicon needed for a cell. One is that their process wastes less silicon and energy to produce a wafer of any given thickness. The second is that producing much thinner wafers than used today by most cell manufacturers would be "no problem." Material usage is an area identified by KIC-Innoenergy with its DELPHOS tool as having considerable potential for cost reduction (Figure 3). Masson showed it already accounts for a considerable proportion of cell and module costs (Figure 4).

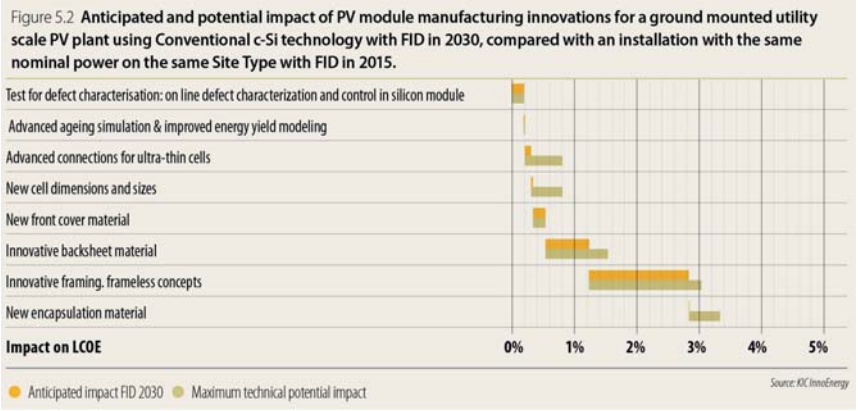


Figure 3 Taken from slide 9 of Javier Sanz's (KIC-Innoenergy) presentation. It shows the scope for cost reduction in different parts of the PV manufacturing process, with wafers (as "New cell dimensions and sizes") identified as an area of high potential. Sanz said most of the requests for equity financing made to KIC Innoenergy concern PV and that he has "more capacity to fund than there are suitable projects."

PERC dominant for the next ten years

Much the biggest shares of investments around the world will be in PERC and conventional crystalline silicon (c-Si) lines, said Jäger-Waldau, with "announcements for 20 GW of new PERC capacity having been made for the next 18 months." This matches the areas that private and public research budgets are focused on, said Martin Hermle, "because there, too, the main driver is technology coming to market in the next few years."

ITRPV's roadmap predicts a steep increase in the market shares of PERC and closely related technologies for the next 7 years (Figure 6) in the c-Si segment.

Taking a leap with heterojunction technology

3Sun is blazing a trail in deploying heterojunction ("HJT") and will contribute to the 10% annual market share expected for this technology by 2025 (according to Figure 6). Its adoption, according to Martin Hermle of Fraunhofer-ISE (Figure 5), will be driven by the quest for higher efficiency, in turn leading to a levelised cost of electricity (LCOE) that is the lowest of all technologies in the near term (2020 – Figure 4).

3Sun is currently Europe's boldest (in terms of scale and technology choice) investment in cell/module manufacturing. EU funding from Horizon 2020 is helping EGP adopt the new technology (AMPERE project).

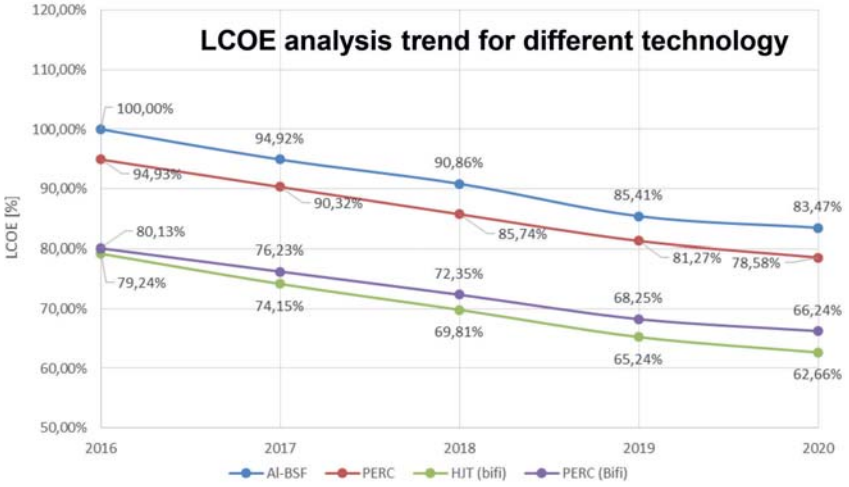
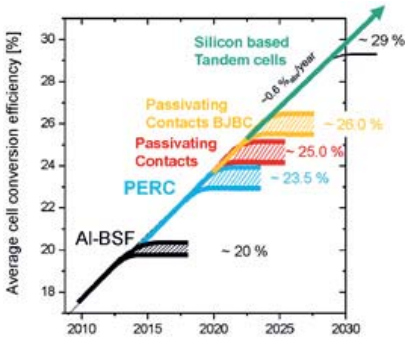


Figure 4 EGP's view on the LCOE of different c-Si-based technologies. The speaker was asked if modules from the plant will be available on the open market. No, he said, but they will be used by EGP in its power plants around the world. Not all module buyers are prepared to pay a higher price (in this case, initially approx.; 48 cEUR/W_p[4]) for high performance modules, even if they offer higher returns in the long term. Bifi = bifacial – cells and modules capable of converting light to electricity on both sides. Generally, these are ground- or roof-mounted on a relatively reflective surface.

[4]*Photon International April 2017 "Three Suns, two faces" p37*



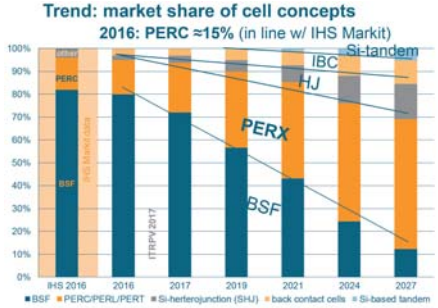


Figure 5 (left) By 2025, the efficiency gains of more mature technologies will have been exhausted and silicon tandem cells will be the only option left (adapted from a chart by Fabian Fertig of Hanwha Q-cells). Figure 6 (right – slide 23 of Axel Metz's presentation) ITRPV expects demand to come for this more efficient technology.

Massive R&D investment brings massive results: the First Solar example

One company in the world, First Solar, commercialises cadmium telluride (CdTe) thin film technology. It increased the average efficiency of its commercial modules by 35% (relative) between Q1 2012 and Q1 2017, from 12.4% to 16.7%, "and will probably reach 18% in a year's time," said Jäger-Waldau. This increase is far greater than other technologies have achieved, whether thin-film or crystalline silicon-based, he showed. Wim Sinke of ECN charted its progress in Figure 7.

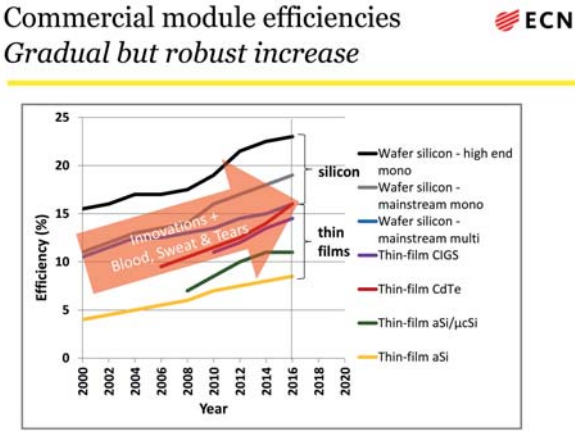


Figure 7: The efficiency of all technologies has increased. The rate of increase appears to be accelerating for CdTe and to have halted for aSi/µSi. The label on the arrow hints at evolutionary progress in technology being largely responsible for the efficiency gains (see heading Crystalline silicon players bet on evolution, not revolution). Efficiencies obtained on lab-scale samples have also been published[5].

[5]*Slide 26 of this Fraunhofer-ISE presentation gives data on the efficiency of CdTe cells in the lab*

Over the same period, First Solar spent vastly more on R&D than companies selling other technologies (Figure 8).

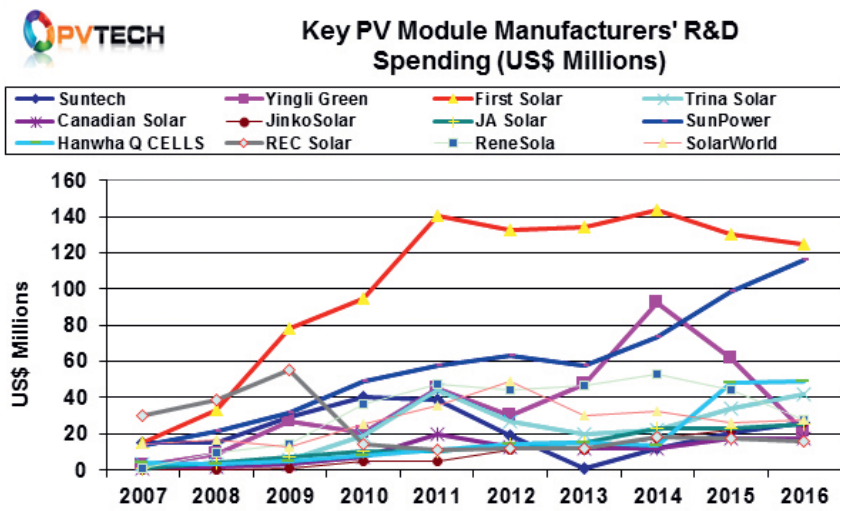


Figure 8 Author: Mark Osborne, founding editor of dedicated B2B website PV-Tech.org. Data appears in sister journal Photovoltaics International. PV Tech's annual report tracks 12 key PV module manufacturers from SunPower and First Solar at the leading edge to high-volume producers such as Trina Solar and Jinko Solar. The companies' manufacturing operations are in China, SE Asia, USA and Europe. First Solar has invested substantially more than its rivals in R&D since the start of the decade.

CdTe's higher efficiency is having an impact on its competitiveness, said Jef Poortmans of IMEC, allowing savings on the balance-of-system components for installers of the modules. It is also pushing down manufacturing costs per watt, and allowing the company to match the price per watt of its c-Si competitors (Figure 9).

[5]*Slide 26 of this Fraunhofer-ISE presentation gives data on the efficiency of CdTe cells in the lab*

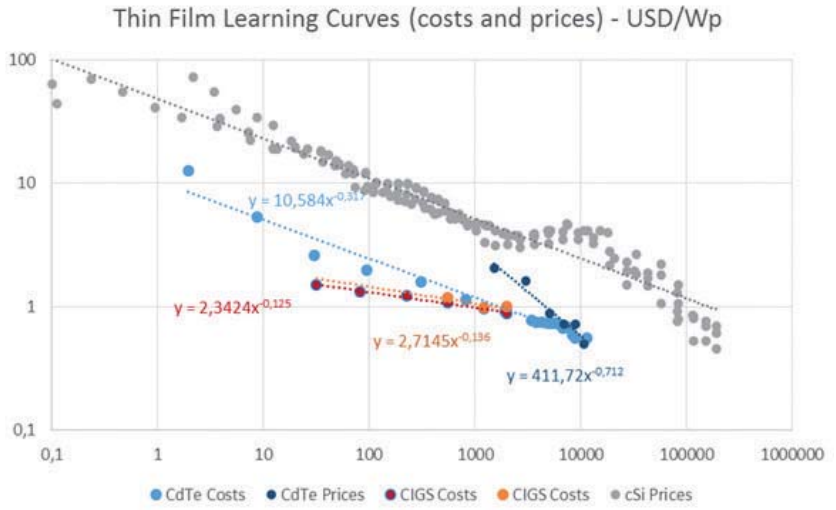


Figure 9 Source: Becquerel Institute 2016. The price per watt of CdTe is close to the price per watt of c-Si technology, and both are declining at the same rate for every doubling of cumulative installed capacity. Production of CdTe modules has risen substantially since 2013.[6]

CIGS struggling?

Although few data points are plotted for CIGS in Figure 9, those that are suggest that while costs are lower than c-Si and CdTe for the same capacity installed, "the perspective for cost reduction of CIGS seems limited," said Masson. Peter Wohlfart of Singulus was more optimistic: "There is a lot of life beyond silicon. There is now an opportunity for equipment suppliers to help bring thin film technologies apart from CdTe into mass production." His company had received a large order for thin-film equipment (mentioned earlier).

Multijunction solar cells and CPV - one European leader

Gerhard Strobl described his company, AZUR SPACE Solar Power GmbH, as a "world market leader" in triple-junction solar cell technology for space applications. Together with Fraunhofer-ISE, AZUR has adapted this technology for high-concentration terrestrial photovoltaic systems and offers a cell product with 44% efficiency at 500-1000x magnification. A 46%-efficient product is due to launch in the next two years. All production takes place at its site in Germany, which will continue also to cover at R&D and assembling of solar cells. If AZUR would produce only terrestrial CPV cells and nothing for space application (which currently is the main product), its installed cell capacity would amount to 500 MW/year. AZUR offers companies know-how and training for local manufacture of CPV modules, trackers and controls.

[6]*Slide 22, Photovoltaics Report presentation, Fraunhofer-ISE*

3 Elements of a strategy

Pursue high quality

James Watson (Solar Power Europe) said cells and modules were areas that Europe "should not give up on" but attempts to produce multicrystalline silicon cells should be abandoned in favour of better-performing technology. If the EU wants to compete, it should "become a leader in next-generation PV products." This is consistent with the recommendation made in the study 'Assessment of Photovoltaics' carried out for the European Commission[7].

European companies seem happy to occupy that space, particularly where "next-generation" is synonymous with "high-end". In wafer production, Nexwafe thinks its high-throughput in-line silicon deposition technique to produce epiwafers will allow its customers to produce some of the most efficient cells on the market. Stefan Reber, Nexwafe representative, said his company will bring "long-term competitiveness to Europe by creating a scalable and highly profitable business."

Eric Ast of Stäubli said his company, which makes electrical connectors, derives 70% of its turnover from China even though his products are "typically 30% more expensive" than those produced by Chinese firms. Equipment supplier Von Ardenne has "chosen to be a leader in terms of quality, know-how and processing glass very close to the softening point," representative Martin Fischer said. "The capital cost of our machines is not comparable to what you can find in China, but we offer very competitive cost of ownership. We're helping our customers scale up to larger substrates, which means further lower costs for them."

But as Ast pointed out, "not everyone wants to pay a premium price" and some companies are guilty of "overengineering their products", "trying to convince customers they need a Ferrari when what they want is a car for going to the shops." Sunpower, represented at the conference, is choosing to expand the downmarket end of its product range[8]. The company makes 22%-efficient modules based on IBC cells, but it recently announced an expansion of its 19%-efficient 'P-series' range based mono-PERC technology. The new capacity would be built in China by Sunpower's joint venture. Jäger-Waldau commented, "It is essential for them that they have a broader range of products, and not only the high-end products, in order to serve more markets."

"Quality" is a somewhat broader notion than "high-performance", but both are routes to better LCOE. "Innovative products of the highest quality" remain an area that Lithuania's PV cluster wants to focus on. The cluster members are focusing on "new materials for modules offering 50 year-lifetimes". Nitzschke said Solarworld was selling a lot of modules to replace ones that had failed after 10-15 years. "People might be satisfied with ground-mounted modules lasting 20 years or less," he said, "but roof-mounted modules have to last as long as possible." Longer lasting modules need a highly automatised production process because "fewer hands involved means a lower failure rate." They are also checked thoroughly, running through "50 testing stations before they are approved for delivery." Automatisation happens also to be the "only way" for European manufacturing not to be undercut by low-wage countries, and he takes pride in his being the

[7] *Assessment of Photovoltaics (PV) Study 2015/RTD/SC/PP-03601-2015*
[8] *See Sunpower investor conference call 5 April 2017*

3 ELEMENTS OF A STRATEGY

company with the "the highest automatisation rate – our workers are only watching on monitors." 3Sun, too, "is fully automated" and its new fab will use "'augmented reality' tools such as i-glasses" to facilitate "man-machine interaction" (Andrea Canino's presentation, slide 20).

The challenge for quality, Nitzschke said, is the end-customer's unwillingness to pay for it. While Chinese module manufacturers made sure they had a "sales point or local presence" in the markets they served, said Ast (with Watson adding this applied to Wacker in China), their European counterparts should have focused a little less on technology development and a little more on fostering acceptance of their high-end products. Alternatively, manufacturers can become their own customers (see later section, Vertical integration). Re-iterating his earlier point that a module's cells are, to a large extent, its defining feature, he asked where the drive to search for better technology would come from if the market embraced the philosophy of cheap-and-cheerful modules. The different set of constraints governing the design of such modules, in his view, would slow down progress on cost reduction.

Quality labels would be one way to sensitise end-consumers, thought de Marliave. The labels could emerge from a private sector initiative without a government mandate: "This happened in the car industry for crash tests." A national or European label for quality "in various senses" would "certainly be a good way to go". Nitzschke referred to the rules for participating in French tenders, which are open only to installations meeting sustainability criteria related to carbon footprint. While "not ideal", he felt the French approach "helps a lot" and would be "even better if it took in quality factors, reliability factors, too." Any labelling scheme open to Chinese products would have to be policed intrusively, implied Daval: he "goes to the line and looks" rather than trusts what is claimed on their spec sheets.

Solve a problem for your customer and market it well

Two speakers, Stuart Brannigan (AEG Industrial Solar) and Daval (KiloWattsol), from companies in the downstream end of the value chain, took the position that the solution to the problems facing PV in Europe could be fixed by the sector itself through normal commercial practice. Believe in this world-conquering technology, Daval implored the audience. Both argued passionately for innovation in PV applications. Daval recalled his time at SNEC[9], where Huawei presented its inverters on a "huge" stand. "It is the number one supplier of inverters in China and number one or two in the world by volume. They displayed only six models because they don't sell inverters – they sell final benefit to the client. They are selling solutions. They don't need to show the hardware." Other examples he mentioned related to installation: "Sunpower's Helix series is like an IKEA kit – something that a carpenter, who have no electrical knowledge but who knows roofs – can install" and "Photowatt's 6 kg module – good for warehouse roofs that can't cope with 20kg/m2 Chinese modules." Brannigan pointed to smart technology that would enable trade of PV electricity within a locality and mentioned the high share (45%) of Solaredge modules in new Belgian and Dutch installations, which he attributed to their special junction boxes. "The functionality of these junction boxes is not fully exploited on rooftop systems," he said, "but that's not the point: the company has hit on something for which there is consumer demand." He mentioned a developer that, through the way it "presents products to the end-user" can persuade some to pay 61 c€/W_p for a module that others pay 38 c€/W_p for. Total is also keen to provide energy services: "We're going into energy services for the end-customer. in Africa, we swap diesel for gas and solar. Trucking gas and building solar farms works out cheaper than a genset, which is the standard way to plug the many holes in supply. This is a large outside market," said de Marliave.

[9] *Annual PV exhibition in China. In 2017 it took place in April.*

Reber thinks his company's epiwafer product responds to customer needs for uniformity (a narrower distribution of the efficiencies can be obtained from cells made with the wafers), the possibility to make thin wafers, a square wafer shape and growth of the pn junction in situ. Both he and Wohlfart were explicit about the need to attend to the customers' needs.

Occupy niches if the opportunity presents itself

Europe could be competitive in niches such as BIPV (building-integrated PV, where a structural component includes an electricity-generating capability using PV). ETIP-PV has looked at BIPV in depth[10]. The market is small – 200-300 MW annually, said David Moser (EURAC) – but large enough to attract the attention of Lithuanian manufacturers, said Ulbikas, "Our companies' strategy is not to develop mainstream products. As small producers, they look to niche markets including BIPV, in which they can still compete on the market." More generally, "flexible production capacity" is key, and not a characteristic of Chinese giga-fabs, thinks Daval. It would need to be supported by an adaptable and quick-thinking R&D workforce. Niches don't necessarily have to be low-volume, said Poortmans, "Demand for BIPV is growing." Hermle said it "could grow very large." Van Hooff said it was an area where Dutch companies "were very active."

Other niches include "I2PV" ("infrastructure-integrated PV" – example of a PV road in the Netherlands[11]) and PV on cars.

Even a niche PV product will need finance for its development, warned Perezagua, and its backers will face the same uphill struggle as producers of standard PV products. On the other hand, said Poortmans, in BIPV, the PV component is not centre-stage, rather the original function the building element should serve. This means that if PV functionality can be integrated at a low enough cost[12], the market will be determined by the demand for the building element rather than for PV. The size and dynamics of this market are well known, perhaps making business plans based around demand for building elements easier to finance. Components made from thin-film technology, which is well suited to façades and semi-transparent windows, could be manufactured simply, with the active layer deposited at the site of glass-manufacture, and the glass then cut at a different site to the shape that the end-customer desires.

Solar cells for space applications are a niche, but still one where a European company is competitive. AZUR considers its cells provide 7% more energy than its competitors' in geostationary orbit due to their better radiation resistance (Gerhard Strobl).

[9]Annual PV exhibition in China. In 2017 it took place in April.
[10]Conference 2015 (see footnote 12); Position Paper 2016
[11]https://www.sciencealert.com/solar-roads-in-the-netherlands-are-working-even-better-than-expected
[12]ETIP-PV's 2015 conference, Energy Efficiency in Buildings and BIPV: Where Sustainability meets Aesthetics, showed that in the minds of some, the value of the electricity generated from BIPV elements was secondary.

3 ELEMENTS OF A STRATEGY

Diversify

Having a non-PV business was seen as a good way to survive hard times. Gerhard Strobl said his company's reputation in space solar cells had opened up other opportunities in optoelectronics. Diversification, he said, "stabilises" companies. Fabrice Stassin of EMIRI said that producers of advanced materials are "protected by scope effects." Advanced materials products are used in many industries and sold outside Europe. Diversification within the realm of PV is possible, too, with Philippe Malbranche (CEA-INES) and Sinke giving the example of vehicle-integrated PV. Peter Wohlfart of Singulus said that although it is crucial to have a "core competence" (in his company's case, plasma processes), one has to "react to developments in the market" and take opportunities to supply to related industries to e.g. deposition equipment for crystalline silicon.

Consider vertical integration

3Sun's strategy is deep vertical integration: it will not just make cells and modules but use them in installations owned by 3Sun's parent company EGP. First Solar, too, builds projects with its modules, and Sunpower for some of its production.

In a perfectly functioning market, a company's choice to integrate vertically or not should not matter to its profitability, said Nitzschke. His company, Solarworld, pursues a shallower form of vertical integration, selling modules made from its own cells. But in the non-ideal world of PV commerce, vertical integration allows you, "if you manufacture cells too expensively", "[to] be your own customer until such time as you can reduce your costs. It is an insurance against downturns – not going out of business because your customer suddenly buys from someone else". A further advantage is that "keeping a foot in every step of the production process helps to ensure quality." The disadvantage is that "you always have a full set of costs and you're not in the position of a module manufacturer who's able to just source cells for a reasonable low price and track prices downwards." Solarworld chose to stay in cells because "cell technology is where the core improvements will be in PV. If you manufacture based on sourced cells, you won't therefore be any better than your competitor sourcing the same cells."

Daval thinks the scaling up of the industry will drive vertical integration: "As an installer of large quantities of PV, you can't buy your modules from one supplier one time and another the next. Long term partnerships must form. This will help the PV industry to become a reliable technical partner for the new entrants making the installations."

De Marliave said Sunpower, too, was an integrated company, manufacturing cells in the Philippines and assembling them into modules in South Africa, Mexico and France. The heritage of its parent company, Total, which pursues upstream and downstream activities in oil and gas, makes it comfortable with vertical integration.

Gain access to capital

Emiliano Perezagua, consultant, said "two or three" attempts he had made to find money to build a PV manufacturing plant in Europe had failed. Nor is there anyone to pay for "African installations" despite the continent's enormous potential. They face high costs of capital. De Marliave agreed and said Europe needs to create a variety of instruments to make "made-in-Europe" modules affordable to foreign installers. It's not the only problem, said Christoph Mayr of Austrian PV Technology Platform, African countries are using requirements to limit imports, citing needs for UV resistance and extra protection against humidity. Perezagua considered it a possibility that Africa would one day follow Brazil, Mexico and other South American countries in building module assembly plants.

In France, said Daval, the illogical situation can arise that a company can win a tender awarded by the ministry to install an amount of PV, but a public bank will not then finance the installation. Brannigan said that at least for the residential market, capital was available. Homeowners have savings, he implied, "they just need to realise that it's a better investment than getting 0.5% in their bank accounts." Concerning investments in manufacturing specifically, Total can typically borrow 50% of its capital requirement for a project from private banks, said de Marliave. 20% would come from Total's own pocket (equity) and 30% from a public bank "like the IFC, EIB or World Bank." In this scenario, the return on equity can be quite attractive. Jäger-Waldau felt that Europe in general suffered from a "mentality problem" concerning industry: "banks demand profit margins of 35% to start an industry – can't 10% be enough?"

In China, a huge expansions of manufacturing capacity can be triggered with only a 3% profit margin. Europe's Minimum Import Price (an anti-subsidy and anti-dumping measure) restored the margins of Chinese module makers to this level and "within 2 years, almost two dozen companies invested in about 20 GW of new production capacity." Not a single watt was invested in Europe, Jäger-Waldau observed.

"In Asia," said de Marliave, "policies, including low cost of capital, are made to attract investment. Access to capital is Europe's drawback, but it's not the only factor. To make a cheap battery you need cheap energy, efficient regulation, low-cost gas. Part of the success of the Chinese is to build a new and efficient ecosystem."

It's not true that the Chinese government had provided huge direct cash injections to PV companies, said Jäger Waldau, "Actually, two state banks gave loan guarantees of 60 bn USD to commercial banks to guarantee loans they would make to private PV companies. This reduced the cost of borrowing for those private companies. Only 3 billion needed to be drawn from these credit lines, to my knowledge."

He cited, as an example of other countries' subsidies, the deal that Solarcity got in New York State: "$500 M in loans" for equipment from the New York Investment and Innovation Fund, and $1 dollar a year in rent — plus utilities — for 10 years in exchange for investing $5 billion in capital, operational and other expenses over that time[13]. "The EU can't do this. The Member States would cry foul if the Commission gave such support to a particular country, because everybody wants to have it." What the EU does have is the European Fund for Strategic Investments, but it demands substantial private cofinance for its loans.[14]. It is the fault of "the banking industry and national governments" that "unfortunately this private finance has not appeared." European law is too rigid, agreed Nitzschke, "If you're a start-up, great; when you're successful, no problem... but when you're struggling, e.g. because of unfair competition, but you still have a chance to be leading in an industry, you can't hope for any help from official funding. This really is a pity. It affects a lot of industry." It is something he expects an industrial policy, if Europe created one, would change. Watson, in combative language, recalled the industrial policies of the 1970s and the willingness of the EU to subsidise Airbus in the face of US irritation. This gung-ho spirit is missing today for PV. He called for a "realistic" industrial policy for PV that does not "carry that onerous cross of 'we can't have state aid – we have to have free markets'."

Silver lining

Over-generous feed-in tariffs were a huge mistake in Italy, enriching banks and solar farm developers without helping European manufacturing, contended Massimo Mazzer of CNR. It was partly the industry's responsibility to argue for more sustainable support, he and Brannigan said.

Look on the bright side, responded Perezagua and Donoso. "thanks to these mistakes, the price of PV has got to where it is today. The world owes a debt of gratitude to the Spanish, German and Italian consumers for paying for these feed-in tariffs."

While Watson would fight fire with fire, de Marliave would prefer both sides to put down the flamethrowers (see heading Put fair trade above free trade). Other European businesses active in China give support to that course of action. Their China Manufacturing 2025 report[15] says, "In contrast to the top-down approach that is often taken by the Chinese Government, the EU does not view massive amounts of state funding and subsidies in support of the sale of products as an effective policy tool."

We need to be more "imaginative in how to finance [investments in manufacturing]," said Donoso, focusing on areas where we have technology leadership. Ulbikas believes Lithuania PV cluster's access to European Structural and Investment Funds and been boosted after the government was persuaded to include PV as a "Smart Specialisation" priority.

Push for a home market, but recognise it is no guarantee of success

"Not very much" makes Europe attractive to global companies at the moment, said Brannigan, "because we don't have the market. You need a volume of sales to create the condition for manufacturing in Europe." Watson agreed: "You need a market to sell into, and sub-7 GW per year [Ed. note: last year's installations in Europe] is not enough." So did Jose Donoso, calling a home market a "sine qua non" for developing a manufacturing sector. Andreas Wade had said that the lack of a European market was the only reason his company, First Solar, had ceased production there. Stassin agreed, but said that this measure on its own would not guarantee that European manufacturing, specifically, benefits[16].

[13]Reference: https://www.manufacturing.net/news/2015/11/nys-750m-investment-solarcity-jobs-not-without-risks
[14]Although since Sept 2016 a blueprint exists for a 'European First-of-a-kind SET Project Investment Fund', which could involve EFSI (see Figure 6.2 on page 59 of this report for the European Commission), it is not yet operational

[15]Published under European Union Chamber of Commerce in China, which represents them
[16]In this, he was aligned with the May 2017 report Assessment of PV, which does "not recommend this course of action because it could be rather costly and would not result in major increases in industrial activity in Europe"

Watson, Stassin and Brannigan agreed that Europe's future market would be "legislation-driven". Regarding the measures that would be needed to create that home market, there was no clamour from the conference for more subsidies. It is a "stable framework" that Donoso wanted: a market adapted for technologies with high fixed costs but low variable costs. With this framework, investments in PV installations will be made by the market and less public funding will be needed. "Setting a good target would create confidence," said Jäger-Waldau, who pointed out that the European Commission's proposed target of 27% renewable energy consumption by the EU by 2030 would correspond, according to plausible models, to 50% renewable electricity, up from 29%[17] in 2015 (still too low for Donoso – '27% is nothing'). Allowing himself a small deviation from the EC's official position on the target, Jäger-Waldau said, "A binding sectoral target for electricity would be a good step forward."[18]

Nitzschke said, "There's no link between the size of a market and its attractiveness as a place to invest in manufacturing. Europe had a market of 22 GW/year and lost 90% of its manufacturers in one year. We need a growing market, but it will not be enough to get investors to Europe."

He found support from de Marliave, who said, "a large-scale manufacturer in Europe would need to export 50% of its production to be profitable. […] The industry in Europe should not be focused on supplying the European market. We believe the industry in Europe should be able to supply export markets, which are ten times bigger."

He and Ast, however, explicitly link the siting of their companies' plants to a market nearby. "Nearby" does not necessarily mean in the same country but rather the same region or continent. Slovenia, for example, has a 100 MW/year module producer that "exports 99% of its production," said Marko Topič, chair of ETIP-PV.

Sectors of Europe's PV manufacturing industry that enjoy competitive advantage are "surviving successfully", said Donoso, in part thanks to their export business.

"A market is necessary," concluded Topič, "but not sufficient to deliver a renaissance in PV manufacturing in Europe."

[17] *http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Share_of_electricity_from_renewable_sources_in_gross_electricity_consumption,2004-2015_%25_T2_New.png; hydropower accounted for 38.4% of the EU's renewable electricity production.*

[18] *This is something that the legislator (European Parliament and Council of Ministers) could still introduce.*

3 ELEMENTS OF A STRATEGY

Put fair trade above free trade

Ulbikas said the companies in the Lithuanian PV cluster "are trying to be active in the EU's anti-dumping campaign. For now, it's working." He echoed the hard line taken by BOD Group boss Vidmantas Janulevičius three years ago at the 2014 ETIP-PV General Assembly New dawn for large-scale PV manufacturing in Europe: reality or pipe dream?[19]. Westgaard said, "Europe has to stand for fair market conditions."

De Marliave said, "I feel [looking at the Commission's interest in setting up a Clean Energy Industrial Competitiveness Forum] there is a changing mood in the EC recently. There is a perception that European citizens are expecting more from the Commission than just open borders without exemption: a more protective environment for jobs – better benefits for European citizens in terms of job creation." Nitzschke echoed him, "We have open borders, and that doesn't help the manufacturing industry."

De Marliave said fair trade was in China's interests, too: "Reciprocity of trade practices should be more present and more effective if you want to attract manufacturing in Europe. The wish for fair trade should be shared by all. Even China could be undercut by some other country."

He remarked that Europe "does not yet have a buy-European act", which could be made to apply to public buildings. There are many such buildings and "they would have to give preference to local products" in any tender they launched for PV. Marko Topič concluded, "We like free trade, but expect and require fair trade."

Give more funding for R&D…

Donoso and Ulbikas said more R&D funding was needed, with Ulbikas highlighting a national strategy of focusing on close-to-market projects between research institutes and industry (so-called "high TRL" projects). Ast, speaking for Stäubli said, it "invested a lot of money in technology to differentiate [itself]."

…while calibrating the R&D strategy carefully

Crystalline silicon players bet on evolution, not revolution

As far as crystalline silicon goes, meeting the IEA's "high" scenario of 9.2 TW PV installed worldwide by 2050 can be achieved with "evolutionary technology development", said Metz, "The lesson from the past is that there has been no revolution; there has mostly been an evolutionary approach because companies don't want to replace whole production lines. Their strategy is to add one or two tools or a new material and then with low capex, improve the efficiency or yield." The take-up of PERC technology, which adds "only two steps to the production process" (Hermle), fits this approach.

The members of ITRPV are from across the world, including Germany-based organisations Solarworld and Fraunhofer-ISE. They confirmed Metz's statement. Hermle said, "There are evolutionary paths to increase silicon solar cell efficiency" by about 0.6%/year (absolute[20]) for the next decade. This was amplified by Hans-Martin Henning, Fraunhofer-ISE Director: "Bringing down cost has to happen mainly with

[19] *His comments are captured in this report, page 7*

[20] *ITRPV expresses the same result differently, saying that 7% of silicon PV's learning rate is attributable to efficiency increases (slide 36 of ITRPV Roadmap presentation, Axel Metz)*

innovation. Innovation means that with gradual evolutionary progress we will achieve higher efficiencies (>25% in the next 5 years), reducing production costs by implementing new production technologies."[21] Nitzschke said this approach had enabled Solarworld to stay 1-2 years ahead of its competitors. For example, he expects that within this period "everyone will do bifacial PERC modules with monocrystalline silicon" – a technology in which Solarworld has in the last half-year chosen to concentrate.

China is slower

Chinese companies, it was claimed, are more cautious. Brannigan said, "I worked for Yingli for 5 years – I know Chinese companies very well. There's a complete cultural difference between Europe and that part of Asia. Chinese companies love to make many small refinements to a production process and end up with something better and that can be produced more cheaply, but they have an absolute fear of innovation, design and of leading something." Donoso agreed that a gap existed between Europe's and China's technological prowess. Daval said Europeans firms were "more inventive" than Chinese ones, but added that the lead that non-Chinese companies had over Chinese ones was shrinking. Echoing Nitzschke, he said, "You have to earn your money on your innovation in one year."

But "evolution" is not enough for some

3Sun (building a heterojunction plant) and First Solar (achieving step-changes in efficiency) have been discussed already. Benjamin Strahm of Meyer Burger, which makes HJT manufacturing equipment, the widespread adoption of which is seen by two other expert speakers (Metz, Hermle) as being a decade away, said Chinese companies like to "evolve slowly but Europe could embrace a sudden switch, jumping a [technology] generation."

[21]Speaking at EUSEW, Brussels 22 June 2017 (see 11:39:00)

3 ELEMENTS OF A STRATEGY

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November 2017